Self-Regulation in Preschoolers: Validity of Hot and Cool Tasks as Predictive Measures of Academic and Socio-Emotional Aspects of School Readiness

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SELF-REGULATION IN PRESCHOOLERS: VALIDITY OF HOT AND COOL TASKS AS PREDICTIVE MEASURES OF ACADEMIC AND SOCIO-EMOTIONAL ASPECTS OF SCHOOL READINESS

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SELF-REGULATION IN PRESCHOOLERS: VALIDITY OF HOT AND COOL TASKS AS PREDICTIVE MEASURES OF ACADEMIC AND SOCIO-EMOTIONAL ASPECTS OF SCHOOL READINESS

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I dedicate this thesis to my awesome husband Melvin A. Anaya, who was of great support and encouragement during these two years of graduate work.
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Extensive research on the development of self-regulation has demonstrated that better executive functioning and effortful control during the preschool years are associated with greater kindergarten and early school achievement. Recent findings suggest that self-regulation tasks differ in their assessment of “hot” and “cool” regulation, how these processes map onto effortful control and executive functioning, and may predict school readiness. However, only a few studies have examined the validity of hot and cool regulation tasks (Allan & Lonigan, 2014; Di Norcia, Pecora, Bombi, Baumgartner, & Laghi, 2015; Willoughby, Kupersmidt, Voegler-Lee, & Bryant, 2011), and how they predict socio-emotional competence (Di Norcia et al., 2015) and academic performance (Kim, Nordling, Yoon, Boldt, & Kochanska, 2013). The current study examined the validity of hot and cool tasks as measures of self-regulation and predictive measures of school readiness within a low-income sample. The sample consisted of 64 preschoolers between the ages of three (n= 38) and four (n= 26) who were enrolled in a blended Head Start program. The Preschooler Self-Regulation Assessment, Woodcock Johnson subtests (Letter Word, Applied Problem, and Picture Vocabulary), and teacher ratings of social competence (Social Competence and Behavioral Evaluation) and emotional competence (Emotion Regulation Checklist) were collected in the fall and spring of the school year. Results indicated that performance on the Cool and Hot tasks
was moderate to highly correlated with academic performance and teacher ratings of socio-emotional competence respectively. Developmental differences in self-regulation performance suggested that cool regulation begins to develop later in the preschool period and may depend on earlier development of hot regulatory processes. There were also gains in academic achievement and socio-emotional competence from fall to spring. Regression analyses indicated that Hot and Cool tasks did not predict socio-emotional competence and academic achievement as distinctively as expected. Hot and cool regulation seemed to predict socio-emotional competence and academic achievement in parallel, with the exception of math performance, which was strongly predicted by Cool task performance above and beyond Hot tasks. Results suggest that hot and cool regulation overlap in predicting school readiness.
Introduction

For the past 20 years, developmental psychology has focused extensively on investigating self-regulation and the benefits associated with its development during the preschool years (ages three to five years; Birgisdóttir, Gestsdóttir, & Thorsdóttir, 2015; Bohlmann & Downer, 2016; Tominey & McClelland, 2011). The preschool years are thought to be a critical period when children are quickly developing self-regulation strategies, and, although only two years may seem like a short period of development, five-year-olds consistently show greater self-regulation than three-year-olds (Cole, Dennis, Smith-Simon, & Cohen, 2009; Rothbart, Ellis, Rueda, & Posner, 2003).

The purpose of this literature review is to emphasize how the development of self-regulation during the preschool years is crucial for school readiness. A large body of developmental research has contributed to the working definition of self-regulation and the main components that describe it, including executive functions, effortful control, and the different aspects that undergird these components. There is, however, still a need to evaluate development of regulatory processes from the perspective of these two components, how they can predict school readiness, and the effectiveness of that prediction. There is also a great need for continuing research on individual differences, such as socioeconomic status, that can impact the development of self-regulation and pose a threat to school readiness. Finally, this review examines hot and cool tasks to assess self-regulation and the need to further establish their validity and predictive value.

Defining Self-Regulation

Self-regulation has been defined as the ability to manage and monitor one’s behavior, cognition, attention, and emotion (Thompson, 2009). Compared to children,
adults are proficient at future planning, holding many things in mind, and keeping track of daily tasks, precisely because adults have mastered self-regulation. Children, on the other hand, are still developing these internal controls, and the cognitive processes that underlie self-regulation (Cole, Martin, & Dennis, 2004; Diamond, Barnett, Thomas, & Munro, 2007; Eisenberg, Spinrad, & Eggum, 2010). The overall importance of regulatory processes in predicting school performance has encouraged a large body of research focused on three main areas: defining self-regulation and how it functions, identifying the main components of this construct and their underlying processes, and examining how these components predict school readiness.

### Components of Self-Regulation

The study of self-regulation has been approached from two different standpoints: the cognitive perspective and the temperament perspective. Although these may sound like opposite perspectives, overarching findings from both lines of research overlap in most of the cognitive processes proposed. Both lines of research are discussed here along with their contributions to the understanding of self-regulation.

**Executive functions.** Researchers who studied self-regulation from a cognitive perspective focused on the cognitive abilities that children develop from toddlerhood to preschool that can facilitate behavioral expressions of self-regulation. These cognitive abilities are considered a major component of self-regulation and referred to as executive functions. Executive functions are mental functions that children develop to control basic attention, thinking and behavior, and consist of three interrelated processes including working memory, inhibition, and cognitive flexibility (Lehto, Juujarvi, Kooistra, & Pulkkinen, 2003; Logue & Gould, 2014; Miyake et al., 2000). Children begin to employ
basic forms of executive functioning in the preschool years. Executive functions are the product of a rapid development of the prefrontal cortex (PFC), and are refined throughout the school years (Krikorian & Bartock, 1998). For example, research investigating the gradual development of working memory suggests that four-year-old children have a significantly lower spatial working memory span compared to five-year-olds, whereas the latter age group can perform comparably to seven-year-olds and young adults if the task is easy (Luciana & Nelson, 1998). These results support the existence of an executive brain network even at early stages of life, which must undergo further development and interconnectivity to meet the requirements of more difficult tasks. Working memory, or the limited capacity to temporarily maintain and manipulate information, contributes to children’s self-regulation because it acts as an interface between the processing of external cues (e.g., instructions), short- and long-term memory, and the actions taken (Baddeley, 2012). During the preschool years working memory growth contributes to children’s growing ability to comply with parental requests and carry out short commands (Ghassabian et al., 2014).

A second major executive function that preschoolers must develop is inhibition. Inhibition in developmental research is defined as the ability to constrain a dominant response and rather activate a subdominant response that, although less desirable, conforms to the eminent norm or rule (Diamond, 2014). Research on this function suggests that older preschoolers show greater inhibition compared to their younger counterparts (Lo, 2013), and these results can be mapped onto the rapid development of the brain’s conflict-resolution network called the executive attention network (EAN), which resides in the PFC (van Veen & Carter, 2002). Intuitively, this cognitive process is
a core function of self-regulation because children must adjust and suppress their dominant behavior to comply with others’ requests, which contributes to successful peer interactions and compliance to parents’ or teachers’ commands.

Inhibition, along with working memory, sets the basis for the development of cognitive flexibility (Diamond, 2014), which is defined as the capacity to switch perspectives, attention, or cognitive focus from task to task (Diamond, 2013). Cognitive flexibility comes later in the development of self-regulation, presumably because children must have developed some level of inhibition and working memory before they can engage in this type of cognitive processing (Davidson, Amso, Anderson, & Diamond 2006; Garon, Bryson, & Smith, 2008). This function is associated with emergence of theory of mind (ToM; Bretherton & Beeghly, 1982), and, once ToM develops, children are more capable of understanding others’ perspectives, thinking about a situation in multiple ways, or updating previous notions when new information is acquired (Diamond, 2014). Cognitive flexibility has been studied with behavioral tasks that require switching response rules or switching attention to different features of a stimulus, and this ability to switch perspectives between tasks recruits from diverse regions of the PFC (Luciana & Nelson, 1998).

Developmental neuroscientists suggest that cognitive flexibility for stimulus and response related tasks begins to emerge early in childhood (age four), but its developmental progression is rather long, and children may not show adult-like performance until after age 13 (Davidson et al., 2006; Diamond, 2014; Meiran & Marciano, 2002). Flexibility for stimulus and response tasks recruits from areas of the dorsal premotor cortex (pre-PMd), caudal dorsal anterior cingulate cortex (cdACC), and
rostral dorsal ACC, and builds upon development of the executive attention network (EAN) and its role in conflict resolution. These results are consistent with social development research, which also suggests that as children develop (e.g., from preschool to elementary school), they show greater cognitive capacity to reflect on self and others’ experiences that assists them in dealing with conflict (Bronson, 2000). A more abstract type of cognitive flexibility develops as certain portions of the ACC (such as rostral dorsal and caudal dorsal) acquire function specificity for conflict detection, allowing the child to combine stimulus and response switching, and use this combination as a tool to deal with conflict. This ability to combine stimulus and response switching involves higher-order processes necessary to internally generate cognitive representations, which are consistent with more intricate roles of the PFC in planning, envisioning, and reasoning, among other functions (Kroger et al., 2002; Okuda et al., 2003). In summary, development of cognitive flexibility builds on working memory and inhibitory abilities (Garon et al., 2008). Together, these processes allow for goal-directed behavior, and eventually lead to higher-order executive functions such as reasoning and planning (Diamond, 2014). Furthermore, these processes support one another to carry out goals. For example, working memory supports inhibition by keeping a given goal in mind, allowing the child to remember what response must be inhibited (Diamond, 2013). Research suggests that successful deployment of working memory, inhibition, and cognitive flexibility during the preschool years is essential for school readiness because it is predictive of greater academic achievement in kindergarten and emerging math and vocabulary skills (Alloway & Alloway, 2010; Borella, Carretti, & Pelgrina, 2010).
**Effortful control.** A different body of literature emerged from the work of developmental psychologists who approached self-regulation from a temperament perspective (Kim, 2012; Kiss, Fechete, Pop, & Susa, 2014; Moran, Lengua, & Zalewski, 2013). Researchers who took this perspective focused on the individual differences in children’s reactivity and emotionality, and therefore proposed a more socio-emotional component of self-regulation called effortful control. Effortful control is generally referred to as the ability to inhibit an automatic or dominant response in favor of the activation of a subdominant one (Gartstein, Slobodskaya, Putnam, & Kinsht, 2009; Murray & Kochanska, 2002; Rothbart et al., 2003), and it involves dimensions of inhibitory control, attention shifting, and emotion regulation. It is worth mentioning that this general definition of effortful control is virtually identical to the definition of inhibition found in the executive functions literature (Diamond, 2014). This commonality provides evidence that, to some extent, both approaches (cognitive and temperament) have been tapping into similar constructs but defining them differently.

However, in the temperament approach effortful control and its underlying processes have been directly related to conduct and emotional aspects of development, unlike executive functions. Research findings suggest that poor effortful control is associated with behavioral problems such as negative peer interaction because processes of attentional shifting and inhibitory control have significant implications for how children regulate their conduct (Kochanska, Murray, & Coy, 1997). In this sense, shifting attention away from prohibited items or inhibiting the desire to engage in disruptive activities (e.g., screaming or hitting) will aid children in maintaining good conduct. More recent studies are consistent with this association and suggest that poor effortful control
predicts conduct problems at home and in the classroom (Gusdorf, Karreman, van Aken, Deković, & van Tuijl, 2011). For example, Gusdorf et al. (2011) found that lower scores on parent-reported inhibitory control and attentional focus were significantly correlated with more conduct problems (e.g., temper tantrums, defiance, lying, or stealing) as reported by both parents and teachers on the Strengths and Difficulties Questionnaire (SDQ; Goodman, 2001). Although these findings are consistent with some previous studies, other researchers suggested that how effortful control predicts behavioral problems is far more complex. For example, Murray and Kochanska (2002) found a U-shaped relationship between these variables, proposing that moderate—and not necessarily higher—levels of effortful control predict fewer total behavioral problems, and that higher levels of effortful control predict internalizing behavior problems (e.g., anxiety and compulsivity). Their findings for effortful control and externalizing problems were unclear, because, although a correlation was not significant, their sample was not representative of children with externalizing problems, which could explain the results.

Effortful control can also affect conduct by contributing to children’s socio-emotional competence, that is, how successful they are at regulating their behavior and emotions when interacting with others. Previous findings suggest that higher levels of effortful control are associated with better social skills (Rothbart et al., 2003) because the underlying process of emotion regulation predicts success in dealing with frustration and conflict (Calkins, Gill, Johnson, & Smith, 1999), which directly affects children’s social interactions. In fact, emotion regulation has been found to strongly predict successful peer and teacher interactions (Calkins et al., 1999; Kochanska, Murray, & Harlan, 2000). However, emotion regulation research is extensive and complex, because the process of
emotion regulation itself has been a controversial term to define. Emotions are rapid, volatile phenomena, so the process of regulating them is difficult to separate from emotions themselves or from emotional expressions (Cole et al., 2004). Eisenberg, Champion, and Ma (2004) offered one of the most detailed definitions in the literature, summarizing emotion regulation as the ability to recruit, maintain, and modulate an emotion, including onset, intensity, and how it is expressed both behaviorally and physiologically. Emotion regulation is influenced by child temperament, develops from toddlerhood in the context of caregiver-child emotional interactions, and continues to be refined through the preschool years once the child enters the peer world (Lemerise & Arsenio, 2000).

Emotion regulation also results from PFC development as it builds upon development of cognitive abilities (e.g., language) and executive functions (e.g., cognitive flexibility and inhibitory control), which aid the child in successfully generating and guiding strategies to deal with emotional events. It is not surprising then that emotion regulation recruits partly from similar brain regions as inhibitory control and cognitive flexibility. In adults, the ability to regulate emotions has been associated with areas of dorsolateral PFC, pre-supplementary motor area (pSMA), temporal cortex, and dorsal ACC, which are also related to cognitive control – the adult, mature version of inhibitory control (Banks, Eddy, Angstadt, Nathan, & Phan, 2007; Kalisch, 2009; McRae et al., 2010). Furthermore, emotion regulation appears to be mediated by the Executive Attention Network (EAN), and this idea is supported by functional connections between the ACC and other limbic areas that are activated for emotional stimuli, such as the amygdala (Etkin, Egner, Peraza, Kandel, & Hirsch, 2006). However, emotion regulation
is limited in preschoolers precisely because interconnectivity between the ACC and the limbic system, as well as other regions of the PFC, have yet to be established and refined. Findings suggest that emotion regulation strategies of younger preschoolers (three to four-year-olds) are fewer in number and variety compared to the strategies employed by five and six-year-olds (Stansbury & Zimmermann, 1999). For example, three-year-olds tend to mostly use instrumental strategies, which may include behaviors such as verbal objection, defending, and scape, whereas five-year-olds may use not only instrumental, but distraction and cognitive strategies as well (Stansbury & Sigman, 2000). Additionally, it is not until these older years (five to six) that preschoolers begin to employ emotion regulation strategies that are more socially accepted, such as cognitive reappraisal (Sala, Pons, & Molina, 2014), allowing them to more effectively express or suppress their emotion to meet situational demands. More complex emotion regulation strategies possibly begin to emerge once they can employ inhibition and cognitive flexibility more readily.

Collectively, these findings suggest that although effortful control and executive functions overlap in some processes (e.g., cognitive flexibility and attention shifting), effortful control is more characteristic of the socio-emotional aspects of self-regulation, whereas executive functions reflect processes that are purely cognitive. However, though these results point to a theoretical framework where self-regulation takes place through dual mechanisms (effortful control and executive functions), this conclusion comes from two separate lines of research. Hence, effortful control and executive functions have been studied separately, rather than directly compared in how they account for the development of self-regulation and prediction of different aspects of school readiness.
Individual Differences in Self-Regulation

Psychologists from both lines of research – cognitive and temperament – have also found individual differences in children’s self-regulation that can emerge as a result of biologically based differences in arousal and physiological regulation (Arnsten, 2009; Gunnar & Quevedo, 2007), cognitive development (Bradley & Corwyn, 2002), and/or environmental sources, ranging from parenting to poverty (Brooks-Gunn, Duncan, & Aber, 1997). Furthermore, it is crucial to examine these differences when studying self-regulation, because they shape the context in which self-regulation develops and can moderate how self-regulation influences school readiness. Consistent across the literature were individual differences dependent on environmental sources. However, socioeconomic status (SES) has been one environmental factor most robustly studied by developmental psychologists, revealing results about significant differences between low- and high-income children that begin before the preschool years and extend beyond high school. Findings from the SES literature point to a common conclusion: environmental factors prevalent in low-income homes seem to hinder development of self-regulation, and ultimately result in lower school performance.

Socioeconomic status. Self-regulation is adaptive and vulnerable to environmental influences. The development of self-regulation occurs through a series of feedback and feed-forward processes in response to stimulation that influences gene expression (Luu & Tucker, 2004). In this way, children’s self-regulation is shaped throughout the preschool years in response to experience, and the role that experience plays in shaping self-regulation. This adaptive characteristic of the self-regulation system is particularly relevant in discussing the differences between low-income children and
their higher-income counterparts. SES influences the type of environment into which children will be born and raised as well as the cognitive stimulation they are likely to receive (Bradley & Corwyn, 2002; Noble, McCandliss, & Farah, 2007; Shonkoff & Phillips, 2000).

For example, middle- to high-income households for example, are usually characterized by parents with a higher education, who are married, and who have employment that provides a fair degree of economic stability (Blau, 1999; Mayer, 1997). These parents are also more likely to be socio-emotionally mature (Adler, Boyce, Chesney, Folkman, & Syme, 1993), stimulate their children’s intellects through reading and other educational activities (Klebanov, Brooks-Gunn, McCarton, & McCormick, 1998), afford high-quality daycare (Hofferth & Phillips, 1991), and provide a home environment with fewer stressful events, where children may feel safe (Howes, 1988). Economically disadvantaged households, on the other hand, are usually characterized by parents with less education, residing in deprived neighborhoods, with few resources to provide for their children (Becker, 1981; Brooks-Gunn et al., 1997). These parents are also more likely to spend little time reading to their children or stimulating them cognitively (Bradley & Corwyn, 2002), and have difficulty keeping a home environment free from stress, whether the source be marital problems, economic pressure, physical illness, or emotional health (Bornstein, Hahn, Suwalsky, & Haynes, 2003; Conger, Conger, & Scaramella, 1997; McLoyd, 1990, 1998).

Most of these characteristics of low-income households are usually present together, which may create a predominantly stressful environment (Conger, Rueter, & Conger, 2000). Additionally, as a consequence of these expected characteristics,
impoverished children are at risk of experiencing more unfavorable events through the persistence and depth of poverty, which can have long-lasting effects on the development of self-regulation (Brooks-Gunn & Duncan, 1997; Duncan & Brooks-Gunn, 1997). Examples of these characteristics are family instability and chaos, which are independent of income, but highly likely to be present in economically disadvantaged homes (Conger et al., 1997). The lack of routines and sleeping and eating schedules, as well as enduring several residential moves can hinder development of inhibitory control, an aspect of executive functioning in self-regulation (Brown, Ackerman, & Moore, 2013). Other aspects of instability include job loss, which can lead to economic instability and is linked to inconsistent punitive parenting behavior (Elder, Liker, & Cross, 1984). Additionally, job loss can produce financial strain and psychological distress in the parents, factors that can in turn reduce marital resources and negatively affect parenting behavior (McLoyd, Jayartne, Ceballo, & Borquez, 1994).

Research findings suggest that preschoolers from low-income families show overall deficits in self-regulation abilities compared to preschoolers from middle-income homes (Bassett, Denham, Wyatt, & Warren-Khot, 2012; Garner & Spears, 2000; Smith, Brooks-Gunn, & Klebanov, 1997), likely due to the combination of environmental risk factors common to low-income households. The cumulative risk model proposes that it is the combination of four or more risk factors, rather than any factor alone, that can negatively affect both cognitive and socio-emotional aspects of self-regulation (Sameroff, Seifer, Baldwin, & Baldwin, 1993), and that these effects can take place early in child development. For example, even before birth, children from low-income homes are more likely to be exposed to environmental pathogens (e.g., drugs, cigarettes, alcohol, etc.) and
lack appropriate nutrition and environmental conditions (Brooks-Gunn & Duncan, 1997). Being exposed to any or all of these factors can hinder fetal and early development through interference of migration and organization of neurons, increasing the likelihood of premature birth and low weight, and deficient development of fine motor skills (Needleman, Schell, Bellinger, Leviton, & Allred, 1990). The detrimental results of prenatal exposure to pathogens can also lead to reduced executive functioning, and increase risks for other cognitive deficits that directly affect development of self-regulation and academic performance (Klein, Hack, & Breslau, 1989).

The combination of these risk factors promotes an unstable environment for low-income children, which in turn introduces stressful events that detrimentally affect self-regulation components. Stress is directly related to self-regulation because the neurobiological systems of the latter are based on the activation and inhibition of attentional systems, which are initiated by moderate levels of reactivity (Arnsten, 2009). However, when stress levels are too high, these systems shut down to allow other systems to deal with the stressful event. In fact, Gunnar and Quevedo (2007) found that when stress-related neurochemicals (e.g., cortisol) rose past moderate levels, activation in prefrontal cortex (PFC) declined, which led to a decline of executive functions and attentional capabilities. This evidence suggests that children in poverty have deficits in self-regulation because they are more likely to experience stressful situations daily, which hinder activation of brain mechanisms underlying self-regulation and thus directly prevent stable development of regulation capabilities.

In summary, children from low-income households are at risk for a number of environmental factors and high levels of stress that, when combined, reduce the
likelihood of growing in a setting that fosters self-regulation development. This disadvantage becomes clear when children arrive to the classroom and face difficulties in learning and peer interaction as a product of deficient attentional regulation and socio-emotional competence. For example, preschoolers from low- compared to high-income families are more likely to show deficits in tasks measuring attention, frustration tolerance, persistence, and cooperativeness, among other aspects of behavior regulation that are critical processes for school performance (Bassett et al., 2012; Morgan, Farkas, Hillemeier, & Maczuga 2009).

Methodological Approaches

Through the years, researchers have used different methods to assess self-regulation in preschoolers, including self-reports, direct observation, and direct assessment. Self-reports are usually assessed in the form of questionnaires and are commonly collected from parents or teachers. Direct observations involve observing children at different settings, for example in the classroom, during free play, or at home. Both of these methods are advantageous in that they can be collected from more than one source for a more representative perspective on the child’s self-regulation abilities. Last, direct assessments refer to behavioral tasks that researchers can administer directly to children to measure their self-regulation. The Preschooler Self-Regulation Assessment (PSRA) is an example of a direct assessment (Smith-Donald, Raver, Hayes, & Richardson, 2007).

The PSRA. The PSRA is particularly useful because it can be administered in the field, for greater ecological validity (Smith-Donald et al., 2007). This assessment includes ten tasks that can be divided into hot and cool tasks that measure hot and cool
regulation respectively. These hot and cool tasks have recently emerged as measures of preschoolers’ self-regulation. This method is based on the differentiation between hot and cool regulatory processes, and how they can be assessed through different behavioral tasks (Willoughby et al., 2011).

**Hot regulation tasks.** Hot regulatory processes reflect the socio-emotional aspects of self-regulation, and can be assessed with arousing tasks that elicit emotion regulation processes or inhibitory control (Smith-Donald et al., 2007). For example, the delay of gratification task, usually known as a snack delay task, requires that children delay immediate gratification to later obtain greater reward (Mischel, Ebbesen, & Zeiss, 1972; Schwarz, 1983). Children who can successfully complete this task show the ability to shift attention away from immediate reward, regulate emotions elicited by a long wait (e.g., self-distraction), and inhibit immediate desires (Mischel et al., 2011; Sethi, Mischel, Aber, Shoda, & Rodriguez, 2000).

Hot tasks directly involve emotion; therefore, it is crucial to consider how emotion processing emerges to understand how hot regulation may be expressed in the brain. Although few studies have investigated hot and cool regulation, there are results suggesting that hot regulatory processes engage the orbitofrontal cortex (OFC), an area of the brain directly involved in emotion processing (Happaney, Zelazo, & Stuss, 2004). Early research in affective neuroscience suggested that emotion processes in general take place at more anterior and ventral areas of the limbic system, including ventromedial cortex, amygdala, and the hypothalamus (MacLean, 1949). Similarly, emotion regulation seems to preferentially recruit from ventral portions of the anterior cingulate cortex (ACC), an idea supported by research findings suggesting more ventral-anterior
activation of the ACC when the task involves emotional stimuli (Bush, Luu, & Posner, 2000). This ventral preference of emotion has also been suggested by electroencephalograph (EEG) research suggesting that error detection components that reflect conscious awareness and emotional attribution to errors (e.g., the Pe component) can be sourced back to ventral portions of the ACC (Checa, Castellanos, Abundis-Gutierrez, & Rueda, 2014). These results suggest that hot regulatory processes could possibly be reflected in ventral activation of the ACC because they predominantly reflect emotional processing.

Behaviorally, hot regulatory processes have been found to reflect effortful control, which includes emotion regulation, and performance on hot tasks is thought to predict preschoolers’ socio-emotional competence (Di Norcia et al., 2015). Di Norcia and colleagues measured preschoolers’ performance on hot and cool dimensions of effortful control along with social competence performance. They found that only hot tasks significantly predicted social competence performance beyond gender, suggesting that development of these hot processes is directly related to children’s gains in social competence during preschool and kindergarten. It is important to mention however, that some of the cool tasks included in this study could be considered by other researchers as measures of executive functions (e.g., Reverse Categorization task and Slowing Down Motor Activity task). Thus, some questions remained as to whether hot processes may be the only dimension of effortful control, whereas cool processes reflect executive functions. As stated before, very few studies have been conducted to investigate how hot tasks map onto effortful control and its underlying processes. Hence, there is a need for more studies to establish the validity of hot tasks as concurrent measures of emotion-
related processes of self-regulation and predictive measures of socio-emotional competence.

**Cool regulation tasks.** Cool regulatory processes seem to reflect executive functions directly (e.g., working memory), and are mainly distinct from hot regulation in that they are not arousing or socio-emotional in nature (Willoughby et al., 2011). These cool processes can be assessed with tasks that require the child to follow directions and keep one or more rules in mind (Luciana & Nelson, 1998). For example, the pencil-tap task requires the child to hold the main rule in mind (tap twice when researcher taps once and vice versa), while inhibiting the impulse to imitate the researcher’s action (Smith-Donald et al., 2007). Researchers believe that cool regulatory processes directly reflect executive functions involved in self-regulation, and that performance on cool tasks can strongly predict academic performance (Willoughby et al., 2011).

Differences between hot and cool regulatory processes are not only evident in behavioral research. Distinct from the orbitofrontal engagement of hot regulation, cool regulation activates areas of the dorsal prefrontal regions (Luciana & Nelson, 1998), and the ability to integrate interrelated executive functions (e.g., cognitive flexibility with inhibition and working memory) requires connectivity of temporo-prefrontal circuitries (Malkova, Bachevalier, Webster, & Mishkin, 2000; Tranel & Eslinger, 2000). Studies using EEG have also concluded that in contrast to the ventral source of emotion-related ERP components, more purely cognitive error components (e.g., the ERN) can be sourced back to dorsal portions of the ACC, which reflect more cognitive or executive functions (Checa et al., 2014). This difference could be the basis for differences between hot and cool regulation, and the validity of hot and cool tasks as measures of self-
regulation and their value in predicting school readiness. Our understanding and
application of hot and cool tasks as measures of self-regulation will be enhanced by more
studies that validate their concurrent and predictive validity.

**Practical Implications**

In summary, development of self-regulation during the preschool years is critical
because it can influence how children perform once they enter school (Eisenberg,
Valiente, & Eggum, 2010). Research focusing on the importance of self-regulation
suggests that better performance on self-regulation tasks is associated with better
kindergarten achievement, even after influential factors such as IQ and maternal
education are considered (Kochanska et al., 1997; McClelland et al., 2007). For instance,
preschoolers’ performance on literacy and mathematics assessments depended (to a great
extent) on their ability to self-regulate (Howse, Calkins, Anastopoulos, Keane, & Shelton,
2003). These findings were additionally supported by longitudinal studies that examined
this relationship, and found that self-regulation was consistently associated with
academic-related variables such as emergent vocabulary and math skills (Altemeier,
Abbott, & Berninger, 2008; Blair & Razza, 2007).

Self-regulation not only impacts academic related skills (e.g., emergent literacy)
but also social-emotional skills that contribute to social competence, which in turn
contribute to school readiness (Garner & Waajid, 2012). A review by Liew (2012)
summarized how self-regulation related components (i.e., effortful control) predicted
school performance, and particularly argued that social competence is a mediating
construct in this prediction. Furthermore, studies that have explored the relationship
between self-regulation and social competence support this argument (Barbarin, 2013;
McKown, Gumbiner, Russo, & Lipton, 2009). For example, preschoolers with better regulation showed more positive interactions with peers and fewer negative responses to frustrating events across a variety of social contexts, such as childcare and dyadic play (Ramani, Brownell, & Campbell, 2010). A different study also showed that children better self-regulation displayed fewer externalizing behaviors (e.g., physical or verbal aggression) in response to disappointment, and were given higher social competence ratings by peers, teachers, and parents (Liew, Eisenberg, & Reiser, 2004). In summary, research efforts that can help us understand how self-regulation processes develop and predict specific child outcomes such as school readiness are extremely important to educate parents and teachers and to guide preschool and early school education policies and programs.

The Current Study

The current study aimed to test the validity of hot and cool tasks as measures of self-regulation and predictors of academic and socio-emotional competence. This study was conducted through secondary data analyses of measures that were collected from preschoolers and their teachers during the fall and spring of the 2011-2012 academic year. Hot and cool regulation were assessed through performance on the Preschool Self-Regulation Assessment (Smith-Donald et al., 2007). Academic achievement was defined as preschoolers’ scores on three individual subtests of the Woodcock Johnson (WJ) III Test of Cognitive Abilities (Woodcock, McGrew, & Mather, 2001): Letter-word, Applied problems, and Picture vocabulary. Socio-emotional Competence was determined through teacher ratings of children’s social competence, externalizing and internalizing behaviors, emotion regulation, and emotion lability.
Preschoolers’ fall and spring self-regulation performance was compared to determine self-regulation growth. It was expected that self-regulation would improve from fall to spring, in line with a rapid development of the PFC (Krikorian & Bartock, 1998). This improvement was also expected to vary as a function of age, because previous findings have suggested that hot regulation develops earlier than cool regulation (Di Norcia et al., 2015; Smith-Donald et al., 2007). Due to this developmental difference, 1) we expected that for Hot task performance, three-year-olds would show a significant improvement from fall to spring, but that four-year-olds’ performance would likely be at ceiling even in the fall. In the case of Cool task performance, 2) we expected that four-year-olds would show greater improvement from fall to spring, and that three-year-olds would show little to no improvement as processes of cool regulation may be barely emerging at this age.

A similar set of results was expected for school readiness. Fall and spring academic performance and socio-emotional ratings were compared to examine gains in school readiness. It was expected that 3) both three- and four-year-olds would improve in their academic and socio-emotional competence. However, given the developmental difference of hot versus cool regulation explained above, 4) it was expected that early development of hot regulation would result in greater gains of socio-emotional competence for the three-year-olds, and that later development of cool regulation could result in greater gains of academic achievement for the four-year-olds.

Findings from the hot and cool regulation literature suggest that hot processes reflect emotion and social-related processes (Sethi et al., 2000), whereas cool regulation reflects executive functions (Bassett et al., 2012). If Hot tasks are in fact a concurrent
measure of the socio-emotional component of self-regulation, 5) preschoolers’ fall performance on these tasks should be moderately or strongly associated with fall socio-emotional competence ratings. Likewise, 6) if Cool tasks are a concurrent measure of executive functions, fall cool regulation performance should be moderately or strongly associated with fall academic achievement. Additionally, based on these expected associations, Hot and Cool tasks could potentially predict future school performance. We expect that if greater correlations between Hot tasks and socio-emotional ratings are found, 7) then fall Hot tasks should predict spring socio-emotional competence above and beyond Cool tasks. Similarly, 8) if greater correlations between Cool tasks and WJ composite scores are found, then Cool tasks should be stronger, better predictors of academic performance beyond Hot tasks. Additionally, because we expect age differences in fall to spring self-regulation growth, 9) we also expect that for both Hot and Cool tasks, age should moderate the prediction of socio-emotional and academic competence. Furthermore, 10) we also expect developmental differences between hot and cool dimensions of self-regulation, where hot regulation seems to develop before cool regulation, leading older preschoolers to perform better than young preschooler on Hot and Cool tasks (Bunch & Andrews, 2012; Di Norcia et al., 2015).

Method

Participants

The present study examined archived data originally collected to explore the effect of teacher training in behavior management on children’s classroom behavior. The study received approval from Western Kentucky University Institutional Review Board. Data from 64 preschoolers (48 boys) between the ages of three (n = 38) and four (n = 26),
who were enrolled in a blended Head Start program and classified as a Head Start
enrollment were examined along with reports from their teachers. Head Start eligibility
was determined by federal standards, which places every child within our sample at or
below poverty guidelines. Although the data set included preschoolers classified as
regular Daycare enrollment, the size of this group was too small (n = 18) to use as a
comparison group and was therefore excluded from the analyses. A total of eight lead and
assistant teachers from four classrooms at the Western Kentucky University Child Care
Center participated in the study. Parents were informed of the project via letters sent to
the home, which also requested parental consent for children to participate. No
demographic information was collected other than age, gender, and Head Start
classification.

**Procedures**

All measures from children and teachers were collected two times in the academic
year: early fall and late spring. Trained research assistants administered the PSRA, and
four graduate students administered the Woodcock Johnson subtests in a quiet room at
the preschool, and in separate sessions to avoid participant fatigue. Verbal assent was
obtained from each child before they were removed from the classroom to complete each
assessment. In administering the assessments, assessors provided a child-appropriate
explanation of the activities. Lead and assistant teachers completed questionnaires for
each child who participated in the study. The teachers received a questionnaire packet per
participant, identified with each child’s name and participant number. Upon returning the
questionnaires, all names were marked out for data confidentiality.

**Measures**
**Self-Regulation.** This study examined preschoolers’ performance on the Preschool Self-Regulation Assessment, a direct and practical assessment of self-regulation that was adapted from lab-based assessments to be administered in the field (Smith-Donald et al., 2007). The PSRA consists of ten individual tasks that measure preschoolers’ self-regulation performance: *Balance Beam, Pencil Tap, Tower Task, Tower Cleanup, Toy Sorting, Toy Wrap, Toy Return, Snack Delay,* and *Tongue Task.* The examiner administered these tasks to each child individually, and always in the following order:

1. **Balance Beam.** This task required the child to walk over a 6-ft piece of masking tape. The tape was laid on the floor, and the child completed three different trials. After the first trial, the child received instructions to walk slower in the second trial, and was asked to further slow down in the third trial. The difference between the third and first trial was used to indicate the child’s ability – in seconds – to slow down in compliance with instructions. Higher scores reflected better performance.

2. **Pencil Tap.** This task consisted of 16 total trials, where the child responded with one pencil-tap if the examiner tapped twice, and two pencil-taps if the examiner tapped once. The child received a point for every correct trial, and task performance was measured using total percent correct. Performance on this task indicated ability to follow instructions and motor inhibition.

3. **Tower Task.** This task consisted of both child and examiner building a block tower together. The task included a practice trial first, followed by the actual trial where the examiner rated the child’s level of turn taking as 0 (gives
examiner no turns), 1 (partial turn-taking), or 2 (full turn-taking).

4. **Tower Cleanup.** This task naturally proceeded after the Tower Task, and required the child to put all blocks away. The examiner recorded the time it took the child to put away the first block, and the time at which cleanup was complete. Lower scores – in seconds – reflected better performance.

5. **Toy Sorting.** In this task, the child sorted a handful of mixed toys into their respective categories (e.g., dinosaurs, bugs, bracelets or cars). The examiner recorded the time – in seconds – until the child begun sorting, and the time at which the sort was complete. Lower scores indicated quicker performance.

6. **Toy Wrap.** This task required the child to turn around for 60 seconds while the examiner loudly wrapped a surprise, and the examiner recorded the time until the child first peeked. Higher scores – in seconds – indicated greater impulse control. Additionally, the examiner rated overall performance as 0 (child did not peek at all), 1 (child peeked once), or 2 (child peeked more than once).

7. **Toy Wait.** The Toy Wrap task contained an additional measure of impulse control – sometimes referred to as the Toy Wait. In this task, the child was asked to wait 60 s for the examiner to finish paperwork before opening the surprise. The examiner timed the wait and recorded if the child touched the surprise – in seconds. After the wait the child was allowed to open the surprise – which was a toy – and play with it.

8. **Toy Return.** This task took place after the play period, when the examiner asked for the toy back and measured the time – in seconds – that it took the child to comply. Faster response indicated greater compliance.
9. **Snack Delay.** This task consisted of a series of four trials in which the child had to wait a given time period to eat an M&M. The wait periods increased from trial one (10 s) to trial four (60 s), and the child was required to wait until the end of all trials to eat the snack. The examiner rated the child’s behavior in each individual trial using a 4-point coding system, where 1 indicated failure to wait, and 4 indicated the ability to wait the full period.

10. **Tongue Task.** This task required the child to hold an M&M on his/her tongue for 40 s, while the examiner recorded the time until the child ate the M&M. Higher scores – in seconds – indicated better performance.

All PSRA tasks have yielded high reliability coefficients, ranging in Cohen’s kappas from 0.81 to 1.0 (Smith-Donald et al., 2007), and test-retest reliabilities ranging from .61 to .69 (Basset et al., 2012). Original PSRA principal component analyses showed that Snack Delay, Toy Wrap, and Toy Wait tasks loaded onto an Attention/Impulse Control component of self-regulation, and have been categorized as hot tasks because they tap into children’s ability to delay something that is highly desirable (Smith-Donald et al., 2007). Differently, Toy Sorting, Tower Cleanup, Balance Beam, and Pencil Tap tasks loaded onto a Compliance/Executive Control component of self-regulation, and have been categorized as cool tasks because they measure control and development of executive functions (Smith-Donald et al., 2007). Bivariate correlations showed that the two factors (Impulse control and Compliance/Executive Control) were positively correlated (r = .40**, p < .01).

**Academic achievement.** Academic achievement was assessed using the Woodcock Johnson III (WJ III) Test of Cognitive Abilities (Woodcock et al., 2001),
which consists of three different batteries, each composed of a range of subtests that can be used to assess intellectual and cognitive abilities such as literacy and mathematic skills. The Woodcock Johnson subtests have been used extensively to reliably measure emergent literacy and numeric skills in preschool-age children (Chien et al., 2009; McClelland et al., 2007; Purpura, Hume, Sims, & Lonigan, 2011; Tusing & Ford, 2004). The present study used preschoolers’ performance on three of these subtests: Letter-Word Identification, Applied Problems, and Picture Vocabulary.

1. The Letter-Word subtest required the child to pronounce isolated letters and words that progressively increased in difficulty. The score was based on the highest level completed and provided a measure of the child’s basic reading skills.

2. The Applied Problems subtest involved practical mathematical problems, which the child had to analyze and solve. These problems also increased in difficulty as the task progressed. The child received a score for the highest level completed, which provided a measure of his/her math problem-solving skills.

3. The Picture Vocabulary measured broad oral language and language expression. This subtest required the child to point at named pictures or to name presented pictures.

The Letter-Word Identification and the Applied Problems subtests are part of the Standard Battery, whereas the Picture Vocabulary is part of the Oral Language Battery. Raw scores for each of these subtests were used in all analyses of academic achievement. Schrank, McGrew, and Woodcock (2001) reported split-half reliability coefficients.
between 0.87 and 0.94 for these particular subtests.

**Social competence.** Social competence was assessed with the Social Competence Behavior Evaluation (SCBE) – Revised (LaFreniere & Dumas, 1996), adapted from the original 80 – item scale (LaFreniere, Dumas, Capuano, & Dubeau, 1992). Lead and assistant teachers were asked to complete the SCBE for every child with parental consent in their classroom. This scale consists of 30 items rated on a 6-point Likert-type response format, ranging from (1) never to (6) always. Teachers indicated how often the child engaged in a number of behaviors typically seen in the preschool setting. Furthermore, three 10-item subscales can be computed to measure different aspects of the child’s social interactions: Social Competence, Externalizing Behaviors, and Internalizing Behaviors. The Social Competence subscale includes items designed to measure the adaptability and positive qualities in the child that foster a pattern of prosocial and well-adjusted behaviors. Higher scores on this subscale indicate greater social competence. The Externalizing subscale contains items that measure an array of negative behaviors (e.g., anger, irritability, frustration, etc.) outwardly expressed either in teacher or peer interactions, and that will likely create tension in the classroom. Higher scores on this subscale indicate higher frequency of these negatively expressed behaviors. The Internalizing subscale comprises items designed to measure children’s social maladjustment expressed through withdrawn behaviors (e.g., isolated play, little peer-interaction, anxious, etc.). Higher scores on this subscale indicate more frequent display of these behaviors. Each subscale is scored by the sum of its items. High internal consistency for these three subscales have been previously reported (.80 to .92) as indexed by Cronbach’s coefficient alpha (LaFreniere & Dumas, 1996). Additionally, high
correlations with the original subscales (.92 – .97) and moderate correlations with the Revised Behavior Problem Checklist (RBPC; Hogan, Quay, Vaughn, & Shapiro, 1989) support the scales’ construct and convergent validity. For the purpose of this study, lead and assistant teachers’ ratings were averaged for further analyses as their ratings were found to be highly correlated in the fall ($r = .62; p = .001$) and spring ($r = .64; p = .001$). Within the present sample, Cronbach’s alphas ranged from .82 to .94 for fall and spring for both lead and assistant teachers across all three subscales.

**Emotion regulation.** Emotion regulation was assessed using the Emotion Regulation Checklist (ERC; Shields & Cicchetti, 1997). The ERC consists of 24 items designed to measure children’s emotion regulation, intensity, valence, and situationally appropriate emotional expressions as reported by a third person (i.e., someone who spends substantial time with the child). These items are rated on 4-point scale, ranging from (1) *almost always* to (4) *never*, where *almost always* indicates that a given item is highly characteristic of the child’s behavior. Factor analyses of the ERC have yielded a two-factor loading or subscales: Emotion Lability/ Negativity and Emotion Regulation. Lability/ negativity reflects persistent mood swings, negative affect, and high dysregulation likely expressed by emotional outbursts. On the other hand, emotion regulation reflects the child’s ability to appropriately monitor emotional expressions according to the situation, as well as greater awareness of self and others’ emotions. Each subscale is scored by the sum of its items. The lability/ negative and emotion regulation subscales are negatively correlated ($r = -.50, p < .001$), and yield high internal consistency as indicated by Cronbach’s alphas of .96 and .83 respectively (Shields & Cicchetti, 1997). Additionally, reversed scoring of either subscale provides a composite
score for emotion regulation. The present study used fall and spring ERC ratings reported by lead and assistant teachers for each child. These lead and assistant teacher ratings were averaged for further analyses, given moderate to high correlations among teachers for both subscales: Emotion Regulation \((r = .44; p = .001)\) and Emotion Lability \((r = .66; p = .001)\). Within the present sample, the Emotion Regulation and Lability scales were also negatively correlated in the fall \((r = -.43; p = .001)\) and spring \((r = -.53; p = .001)\). Cronbach’s alphas for the Emotion Regulation subscale ranged from .89 to .92 for fall and spring of both lead and assistant teachers, and alphas for the Emotion Lability subscale ranged from .77 to .85.

**Results**

Descriptive analyses were computed for spring and fall PSRA task performance in order to identify ceiling or floor effects; any task with an overly skewed distribution (> 2.0) was excluded from further analyses. The three Woodcock Johnson subtests were used as individual measures of academic performance. Additionally, composite ratings from the Social Competence, Internalizing Behaviors, and Externalizing Behaviors subscales of the SCBE, together with the Emotion Regulation and Lability subscales of the ERC were used as independent measures of socio-emotional competence. Unlike the PSRA Hot tasks, which measure emotion regulation as a process variable, the ERC measures emotion regulation as an outcome variable, which is based on behaviors and responses within a given context (e.g., school) expected of children who can employ emotion regulation.

**Descriptive Analyses**

Fall and spring descriptive statistics for the PSRA are presented in Table 1. Based
### Table 1.
Fall and Spring PSRA Performance Across Age.

<table>
<thead>
<tr>
<th>Tasks</th>
<th>N</th>
<th>M</th>
<th>SD</th>
<th>Min.</th>
<th>Max.</th>
<th>Skewness</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>F</td>
<td>S</td>
<td>F</td>
<td>S</td>
<td>F</td>
<td>S</td>
</tr>
<tr>
<td>Balance Beam (s)</td>
<td>57</td>
<td>54</td>
<td>1.7</td>
<td>3.4</td>
<td>2.7</td>
<td>5.5</td>
</tr>
<tr>
<td>Pencil Tap (%) correct</td>
<td>57</td>
<td>55</td>
<td>41.4</td>
<td>60.8</td>
<td>31.5</td>
<td>30.4</td>
</tr>
<tr>
<td>Toy Wait (s)</td>
<td><strong>58</strong></td>
<td>55</td>
<td><strong>56.7</strong></td>
<td><strong>58.1</strong></td>
<td><strong>11.2</strong></td>
<td><strong>10.1</strong></td>
</tr>
<tr>
<td>Toy Return (s)</td>
<td>58</td>
<td>54</td>
<td>124.4</td>
<td>84.7</td>
<td>16.3</td>
<td>84.9</td>
</tr>
<tr>
<td>Toy Wrap (s)</td>
<td>58</td>
<td>56</td>
<td>44.8</td>
<td>49.4</td>
<td>21.7</td>
<td>19.1</td>
</tr>
<tr>
<td>Snack Delay (s)</td>
<td>58</td>
<td>56</td>
<td>46.2</td>
<td>50.5</td>
<td>21.7</td>
<td>15.4</td>
</tr>
<tr>
<td>Tongue Task (s)</td>
<td><strong>57</strong></td>
<td>50</td>
<td><strong>35.4</strong></td>
<td><strong>36.5</strong></td>
<td><strong>10.4</strong></td>
<td><strong>7.9</strong></td>
</tr>
<tr>
<td>Tower Task (0-2 scale)</td>
<td>58</td>
<td>56</td>
<td><strong>1.2</strong></td>
<td><strong>1.6</strong></td>
<td><strong>0.8</strong></td>
<td><strong>0.7</strong></td>
</tr>
<tr>
<td>Tower Clean (s)</td>
<td>58</td>
<td>56</td>
<td><strong>29.1</strong></td>
<td><strong>29.3</strong></td>
<td><strong>19.3</strong></td>
<td><strong>17.2</strong></td>
</tr>
<tr>
<td>Toy Sort (s)</td>
<td>58</td>
<td>56</td>
<td>77.9</td>
<td>64.8</td>
<td>31.5</td>
<td>29.3</td>
</tr>
<tr>
<td>N (listwise)</td>
<td>55</td>
<td>45</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Note. F = Fall data; S = Spring data. Tasks in bold were excluded from further analyses due to overly skewed distributions.
on their overly skewed distributions (> 2.0), the following tasks were excluded from further analyses: Toy Wait (-3.4) and Tongue Task (-2.1). Although the Toy Return task seem to meet the criteria for exclusion, descriptive statistics by age group (three- and four-year-olds) suggested that this task captured variability within both age groups when examined separately, and was kept for further analyses. Additionally, some tasks were excluded on the theoretical basis that they did not completely fit under the categories of cool and hot tasks. These tasks were the Tower Task and the Tower Clean-up. These tasks were considered “lukewarm” because they seemed to include both, cool and hot components of self-regulation. Although Toy Sort was also considered to be a lukewarm task, it was included in the correlation analyses as a cool task in order to examine how it was related to measures of executive functions and other cool tasks, given that previous studies have placed it in the Cool task category (Smith-Donald et al., 2007). Fall and spring descriptive statistics for school readiness performance are listed in Appendix A.

Concurrent correlations for fall cool tasks and academic achievement are presented in Table 2. Pencil Tap was the only task that correlated with all Woodcock Johnson subtests of academic achievement. The Balance Beam task only correlated with Letter Word performance, whereas Toy Sort only correlated with performance on the Applied Problems subtest. Although Toy Sort correlated with one of the subtests, this task did not correlate with any of the cool tasks, suggesting that it may not fit under the cool category because it seems to measure a construct different from the construct that Balance Beam and Pencil Tap are measuring. Based on this result, Toy Sort was excluded from the regression analyses.

Concurrent correlations for fall hot tasks and socio-emotional competence are
Table 2. Concurrent Correlations for Cool Tasks and Academic Achievement.

<table>
<thead>
<tr>
<th></th>
<th>Letter Word</th>
<th>Applied Problems</th>
<th>Picture Vocabulary</th>
<th>Balance Beam</th>
<th>Pencil Tap</th>
<th>Toy Sort</th>
</tr>
</thead>
<tbody>
<tr>
<td>Letter Word</td>
<td>-</td>
<td>.56**</td>
<td>.43**</td>
<td>.55**</td>
<td>.39**</td>
<td>.00</td>
</tr>
<tr>
<td>Applied Problems</td>
<td>.36**</td>
<td>-</td>
<td>.58**</td>
<td>.52**</td>
<td>.66**</td>
<td>-.00</td>
</tr>
<tr>
<td>Picture Vocabulary</td>
<td>.12</td>
<td>.53**</td>
<td>-</td>
<td>.33**</td>
<td>.42**</td>
<td>.05</td>
</tr>
<tr>
<td>Balance Beam</td>
<td>.34**</td>
<td>.19</td>
<td>.18</td>
<td>-</td>
<td>.33**</td>
<td>.02</td>
</tr>
<tr>
<td>Pencil Tap</td>
<td>.25*</td>
<td>.67**</td>
<td>.40**</td>
<td>.27*</td>
<td>-</td>
<td>-.14</td>
</tr>
<tr>
<td>Toy Sort</td>
<td>-.13</td>
<td>-.229*</td>
<td>.06</td>
<td>.01</td>
<td>-.19</td>
<td>-</td>
</tr>
</tbody>
</table>

Note. *p < .05; **p < .01. Fall correlations are displayed in the bottom half of the table; Spring correlations are displayed in the top half.
Table 3.
Concurrent Correlations for Hot Tasks and Socio-emotional Competence.

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Toy Return</td>
<td>-</td>
<td>.04</td>
<td>-.14</td>
<td>.00</td>
<td>-.13</td>
<td>-.08</td>
<td>-.03</td>
<td>-.05</td>
</tr>
<tr>
<td>Toy Wrap</td>
<td>-.24*</td>
<td>-</td>
<td>.26*</td>
<td>.48**</td>
<td>-.34**</td>
<td>-.37**</td>
<td>-.49**</td>
<td>.44**</td>
</tr>
<tr>
<td>Snack Delay</td>
<td>-.37**</td>
<td>.60**</td>
<td>-</td>
<td>.24*</td>
<td>.03</td>
<td>-.18</td>
<td>-.27*</td>
<td>.09</td>
</tr>
<tr>
<td>Social Comp.</td>
<td>-.29*</td>
<td>.54**</td>
<td>.49**</td>
<td>-</td>
<td>-.42**</td>
<td>-.60**</td>
<td>-.77**</td>
<td>-.74**</td>
</tr>
<tr>
<td>Int. Beh.</td>
<td>.23*</td>
<td>-.25*</td>
<td>-.147</td>
<td>-.40**</td>
<td>-</td>
<td>.32**</td>
<td>.26**</td>
<td>-.67**</td>
</tr>
<tr>
<td>Ext. Beh.</td>
<td>.22*</td>
<td>-.29**</td>
<td>-.28**</td>
<td>-.52**</td>
<td>.14</td>
<td>-</td>
<td>.88**</td>
<td>-.42**</td>
</tr>
<tr>
<td>Lability</td>
<td>.25*</td>
<td>-.41**</td>
<td>-.44**</td>
<td>-.72**</td>
<td>.11</td>
<td>.84**</td>
<td>-</td>
<td>-.53**</td>
</tr>
<tr>
<td>Emo. Reg.</td>
<td>-.13</td>
<td>.40**</td>
<td>.32**</td>
<td>.69**</td>
<td>-.72**</td>
<td>-.26*</td>
<td>-.37**</td>
<td>-</td>
</tr>
</tbody>
</table>

Note. * p < .05; ** p < .01. Fall correlations are displayed in the bottom half of the table; Spring correlations are displayed in the top half.
presented in Table 3. All hot tasks were significantly correlated with teacher ratings of Social Competence, Externalizing Behaviors, and Lability, and at least two of these tasks were significantly correlated with teacher ratings of Internalizing Behaviors and Emotion Regulation. All hot tasks were also significantly correlated with one another, suggesting they are measuring similar constructs.

**Fall to Spring Self-Regulation Growth**

Fall to spring self-regulation growth was examined through two separate repeated measures MANOVAs: one for Hot tasks and one for Cool Tasks. Each MANOVA was conducted in order to test developmental differences in self-regulation as a function of age (i.e., three- compared to four-year-olds) and wave (i.e., spring performance compared to fall performance). Each repeated measures MANOVA was followed by mixed factorial ANOVA for each individual task to examine significant main effects and interactions. A Bonferroni correction was employed to control for family-wise error for post-hoc comparisons that examined simple effects for any significant interactions. This correction consists of dividing the set alpha ($p < .05$) by the number of comparisons done within each family of comparisons. In this set of analyses, each MANOVA (Hot and Cool) was considered a family of comparisons. Given that these MANOVAs included three tasks each, the alpha level was set at $p < .017$.

**Hot regulation growth.** We used three hot tasks from the PSRA to examine hot regulation growth: Toy Wrap, Toy Return, and Snack Delay. Performance on the Toy Wrap task was measured as the ability to wait 60s without peeking at the toy, with long times indicating better performance. The Toy Return task measured preschooler’s ability to return the toy at the examiner’s request, with lower scores indicating better
performance. Finally, the Snack Delay task measured the ability to delay immediate gratification (one M&M) to receive a greater reward (four M&Ms). In this task, a longer wait indicated better performance.

A 2 (Wave) by 2 (Age) by 3 (Hot task: Toy Wrap, Toy Return, Snack Delay) repeated measures MANOVA was conducted to compare fall to spring hot regulation growth as a function of age. There was a significant multivariate effect of Hot task, $F(2,100) = 62.21, p = .001, \eta^2_p = .55$, and a Wave x Hot Task interaction, $F(2,100) = 11.50, p = .001, \eta^2_p = .20$. Given the significance of the overall test, follow-up mixed-model ANOVAs were conducted for each Hot Task to examine the impact of age and wave on participant performance (Figures 1A – 1C). These analyses revealed a significant main effect of Age for Toy Wrap (1A), $F(1,52) = 16.85, p = .001, \eta^2_p = .25$, where across Waves, four-year-olds ($M = 53.77$) were able to wait significantly longer before peeking than did three-year-olds ($M = 35.90$). This main effect was qualified by a significant Wave x Age interaction, $F(1,52) = 6.61, p = .013, \eta^2_p = .10$. Tukey post–hoc comparisons revealed that three-year-olds waited longer in the spring ($M = 42.95$) compared to the fall ($M = 28.85, p = .01$), whereas four-year-olds’ performance was similar at both times ($M_F = 53.95, M_S = 53.55$). There was a significant main effect of Wave for Toy Return (1B), $F(1,50) = 9.26, p = .004, \eta^2_p = .16$, where both three- and four-year-olds returned the toy to the examiner more quickly in the spring ($M = 83.72$) compared to the fall ($M = 122.03$). Finally, analyses for the Snack Delay task (1C) only revealed a significant main effect of Age, $F(1,52) = 9.61, p = .003, \eta^2_p = .17$, where averaged across waves, four-year-olds waited longer ($M = 53.24$) than three-year-olds ($M = 41.25$) to eat the snack.
Figure 1A–1C. Hot regulation performance divided by task as a function of Age and Wave.
**Cool regulation growth.** We used three tasks from the PSRA to examine cool regulation growth: Pencil Tap, Toy Sort, and Balance Beam. The Pencil Tap task measured preschooler’s ability to tap a pencil according to examiner’s instructions, and performance was indicated by percent correct. The Toy Sort task measured the ability to sort different types of toys into separate categories, with shorter times indicating better performance. Finally, performance on the Balance Beam task was measured as the ability to slow down in the last trial, with longer times indicating better performance.

A 2 (Wave) by 2 (Age) by 3 (Cool Task: Pencil Tap, Toy Sort, Balance Beam) repeated measures MANOVA was conducted to compare fall to spring cool regulation growth as a function of age. There was a significant multivariate effect of Cool Task, \( F(2,94) = 151.04, \ p = .001, \ \eta_p^2 = .76 \), a significant Cool Task x Age interaction, \( F(2,94) = 20.42, \ p = .001, \ \eta_p^2 = .30 \), and a Wave x Cool Task interaction, \( F(2,94) = 11.80, \ p = .001, \ \eta_p^2 = .20 \). Given the significance of the overall test, mixed model ANOVAs were conducted for each Cool Task to examine the impact of age and wave on participant performance (Figure 2A – 2C). The ANOVA revealed a significant main effect of Wave for Pencil Tap (2A), \( F(1,50) = 24.61, \ p = .001, \ \eta_p^2 = .33 \), where both three- and four-year-olds scored a higher percent of correct trials in the spring (\( M = 56.81 \)) compared to the fall (\( M = 36.93 \)), and a main effect of Age, \( F(1,50) = 30.76, \ p = .001, \ \eta_p^2 = .38 \), where across waves, four-year-olds (\( M = 64.96 \)) scored significantly higher than three-year-olds (\( M = 28.78 \)). The analyses for Toy Sort (2B) also revealed a significant main effect of Wave, \( F(1,52) = 6.06, \ p = .017, \ \eta_p^2 = .10 \), where both three- and four-year-olds took less time to sort the toys in the spring (\( M = 67.28 \)) compared to the fall (\( M = 80.77 \)). Finally, the analyses for the Balance Beam task (2C) revealed a trending Wave x Age Interaction,
Figure 2A – 2C. Cool regulation performance divided by task as a function of Age and Wave.
where only four-year-olds seemed to show improvement, slowing down more in the spring ($M = 4.70$) compared to their fall performance ($M = 1.91$). However, these results were not significant under the corrected alpha.

**Fall to Spring School Readiness Comparisons**

Fall to spring school readiness was examined through two separate repeated measures MANOVAs: one for Socio-emotional Competence and one for Academic Achievement. Each MANOVA was conducted in order to examine gains in school readiness as a function of age (i.e., three- compared to four-year-olds) and wave (i.e., spring performance compared to fall performance). Each MANOVA was followed by mixed factorial ANOVAs to examine the impact of age and wave on responses to each individual measure of socio-emotional competence and academic achievement. A Bonferroni correction was employed again to control for family-wise error. Given that Socio-emotional gains constituted a family of five comparisons, the alpha level was $p < .01$. Academic gains were considered a family of three comparisons, and in this case the alpha level was set at $p < .017$.

**Socio-emotional gains.** A 2 (Wave) by 2 (Age) by 5 (Socio-emotional Measures: Social Competence, Internalizing Behaviors, Externalizing Behaviors, Emotion Lability, Emotion Regulation) repeated measures MANOVA was conducted to compare fall to spring gains in socio-emotional competence as a function of age. There were significant multivariate effects of Wave, $F(1,58) = 42.26, p = .001, \eta_p^2 = .42$, and Socio-emotional Measure, $F(4,232) = 191.95, p = .001, \eta_p^2 = .77$. This main effect was qualified by a significant Socio-emotional Measure x Age interaction, $F(4,232) = 10.53, p = .001, \eta_p^2 = $
.15. Given the significance of the overall test, follow-up mixed factorial ANOVAs were conducted for each Socio-emotional Measure to examine the impact of age and wave on participant response (Figure 3). These analyses revealed significant main effects of Wave, $F(1,59) = 11.57, p = .001, \eta_p^2 = .16,$ and Age, $F(1,59) = 23.09, p = .001, \eta_p^2 = .28$ for Social Competence, where teacher ratings of three- and four-year-olds’ social competence were higher in the spring compared to the fall, but four-year-olds were rated higher at both times. There was also a main effect of Wave for Internalizing Behaviors, $F(1,59) = 11.64, p = .001, \eta_p^2 = .17,$ where teacher ratings of participants’ internalizing problems across age were higher in the spring compared to the fall. No other main effects of Wave or Age were found for any other Socio-emotional measure.

Figure 3. Teacher ratings for all measures of socio-emotional competence as a function of Age and Wave. Main effects of Wave are identified by asterisks in-between bars. Main effects of Age are identified by asterisks above bars.
**Academic gains.** A 2 (Wave) by 2 (Age) by 3 (Academic test: Letter Word, Applied Problems, Picture Vocabulary) repeated measures MANOVA was conducted to compare fall to spring gains in academic achievement as a function of age. There were significant multivariate effects of Wave, $F(1,52) = 41.08, p = .001, \eta_p^2 = .44$, Academic Test, $F(2,104) = 38.87, p = .001, \eta_p^2 = .43$, and Age $F(1,52) = 19.17, p = .001, \eta_p^2 = .27$. Given the significance of the overall test, follow-up mixed factorial ANOVAs were conducted to examine the impact of age and wave on each academic test (Figure 4).

![Academic Gains](image)

*Figure 4. Child performance on Woodcock Johnson subtests as a function of Age and Wave. Main effects of Wave are identified by asterisks in-between bars. Main effects of Age are identified by asterisks above bars.*

These analyses revealed significant main effects of Wave for all the subtests: Letter Word, $F(1,52) = 18.21, p = .001, \eta_p^2 = .26$, Applied Problems, $F(1,52) = 22.02, p = .001, \eta_p^2 = .30$, and Picture Vocabulary, $F(1,52) = 19.17, p = .001, \eta_p^2 = .27$, where both age groups showed significant academic gains from fall to spring. The analyses also
revealed significant main effects of Age for all subtests: Letter Word, $F(1,52) = 6.10, p = .017, \eta^2_p = .11$, Applied Problems, $F(1,52) = 31.91, p = .001, \eta^2_p = .38$, and Picture Vocabulary, $F(1,52) = 6.56, p = .013, \eta^2_p = .11$, where four-year-olds performed better than three-year-olds across waves in every subtest.

**Spring Academic and Socio-emotional Competence Predictions**

The validity of Hot and Cool tasks as predictive measures of school readiness was examined via hierarchical multiple regression analyses (Cohen & Cohen, 1983). This approach was employed to account for the interrelationships among predictors, as some of the PSRA tasks were expected to correlate with one another (Appendix B). Separate analyses were conducted for spring Woodcock Johnson subtests (Letter Word, Applied Problems, Picture Vocabulary), spring SCBE scales (Social Competence + Internalizing Behaviors + Externalizing Behaviors), and spring ERC scales (Emotion Regulation, Emotion Lability); predictor variables were Hot and Cool tasks assessed in the fall. All variables were centered using standardized $z$ scores.

**Socio-emotional competence.** Hierarchical multiple regression analyses examining socio-emotional competence predictions were conducted for social competence, internalizing behaviors, externalizing behaviors, emotion regulation, and lability (Table 4 and 5). In these analyses, age was entered into the equation first, as a “fixed” factor that cannot be influenced by another variable. Cool tasks (Balance Beam and Pencil Tap) were entered next (Step 2), followed by Hot tasks (Toy Wrap, Toy Return, and Snack Delay; Step 3), in order to test the hypothesis that hot regulation would predict socio-emotional aspects of school readiness above and beyond cool regulation. Finally, we included interaction terms between age and each of the five PSRA
Table 4.
Hierarchical Regression Analyses for SCBE Ratings.

<table>
<thead>
<tr>
<th>Step</th>
<th>Predictor</th>
<th>Social Competence</th>
<th>Int. Behaviors</th>
<th>Ext. Behaviors</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>$F(\text{Change})$</td>
<td>$\Delta R^2$</td>
<td>$\beta$</td>
</tr>
<tr>
<td>1</td>
<td>Age</td>
<td>19.72*</td>
<td>.22*</td>
<td>.47</td>
</tr>
<tr>
<td>2</td>
<td>Cool Tasks</td>
<td>15.44*</td>
<td>.19*</td>
<td>.04</td>
</tr>
<tr>
<td></td>
<td>Balance Beam</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Pencil Tap</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Hot Tasks</td>
<td>8.83*</td>
<td>.04</td>
<td>1.43</td>
</tr>
<tr>
<td></td>
<td>Toy Wrap</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Toy Return</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Snack Delay</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Total $R^2$</td>
<td>.41*</td>
<td>.02</td>
<td>.21</td>
</tr>
</tbody>
</table>

Note. * $p < .01$. Last two steps of the equation are not displayed given their lack of significance.
<table>
<thead>
<tr>
<th>Step</th>
<th>Predictor</th>
<th>Emotion Regulation</th>
<th>Lability</th>
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<tr>
<td></td>
<td></td>
<td>$F(\text{Change})$</td>
<td>$\Delta R^2$</td>
</tr>
<tr>
<td>1</td>
<td>Age</td>
<td>1.52</td>
<td>.02</td>
</tr>
<tr>
<td>2</td>
<td>Cool Tasks</td>
<td>3.45</td>
<td>.11</td>
</tr>
<tr>
<td></td>
<td>Balance Beam</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Pencil Tap</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Toy Wrap</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Toy Return</td>
<td>2.44</td>
<td>.05</td>
</tr>
<tr>
<td></td>
<td>Snack Delay</td>
<td></td>
<td></td>
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<td></td>
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</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Total $R^2$</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Note.* $p < .01$. Last two steps of the equation are not displayed given their lack of significance.
tasks: Cool tasks (Step 4) followed by Hot tasks (Step 5). After Bonferroni corrections were used for each regression analysis, the alpha level was set at $p < .01$ based on the number of predictors included in the regression equation.

Results of these regression analyses indicated that Age and Cool task performance in the fall accounted for the majority of total variance explained in the equations (21 – 41%). Contrary to our hypothesis, Hot tasks did not explain any additional variance beyond that explained by Cool tasks. In the context of interaction effects, none of the terms reached significance.

**Academic achievement.** Hierarchical multiple regression analyses examining academic achievement predictions were conducted separately for Letter Word, Applied Problems, and Picture Vocabulary performance (Table 6). Steps for these analyses were similar to those of the socio-emotional analyses, except that the order of Hot and Cool tasks was altered. Age was entered first again as a “fixed” variable that cannot be influenced by other variables. This time, Hot tasks (Toy Wrap, Toy Return, and Snack Delay) were entered next (Step 2), followed by Cool tasks (Balance Beam and Pencil Tap; Step 3) to test whether cool regulation would predict academic achievement beyond hot regulation. Finally, Steps 4 and 5 included the same age by task interaction terms included in the socio-emotional analyses, except that the Hot task interaction terms were entered first (Step 4) followed by the Cool interaction terms (Step 5). After Bonferroni corrections were used for each regression analysis, the alpha level was set at $p < .01$ based on the number of predictors included in the regression equation.

Results for academic achievement analyses indicated that for Letter Word and Picture Vocabulary, neither Hot nor Cool task performance explained any additional
Table 6.
Hierarchical Regression Analyses for W.J. Subtests of Academic Achievement.

<table>
<thead>
<tr>
<th>Step</th>
<th>Predictor</th>
<th>Letter Word</th>
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<th>Applied Problems</th>
<th></th>
<th>Picture Vocabulary</th>
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<tbody>
<tr>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>Age</td>
<td>12.83*</td>
<td>.20*</td>
<td>.45</td>
<td>23.65*</td>
<td>.26*</td>
<td>.51</td>
</tr>
<tr>
<td>2</td>
<td>Hot Tasks</td>
<td>3.20</td>
<td>.01</td>
<td></td>
<td>9.69</td>
<td>.12</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Toy Wrap</td>
<td>- .03</td>
<td></td>
<td></td>
<td>.14</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Toy Return</td>
<td>-.15</td>
<td></td>
<td></td>
<td>-.28</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Snack Delay</td>
<td>.07</td>
<td></td>
<td></td>
<td>.07</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Cool Tasks</td>
<td>3.06</td>
<td>.08</td>
<td></td>
<td>10.81*</td>
<td>.13*</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Balance Beam</td>
<td>.27</td>
<td></td>
<td></td>
<td>.35</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Pencil Tap</td>
<td>-.07</td>
<td></td>
<td></td>
<td>.11</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Total R^2</td>
<td>.20</td>
<td></td>
<td></td>
<td>.52</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Note. * p < .01. Last two steps of the equation are not displayed given their lack of significance.
variance beyond age. However, the hypothesis for cool regulation and academic achievement was confirmed for the Applied Problems subtest, where Hot tasks predicted performance beyond age, and Cool tasks predicted performance above and beyond Hot tasks. In the case of the interaction effects, none of the terms reached significance.

**Discussion**

The development of self-regulation is of prime importance given its significant influence on children’s school readiness and future school performance (Ghassabian et al., 2014. Kochanska et al., 1997). Development of self-regulation during the preschool years has been specifically associated with greater academic achievement, better social skills, and perseverance (McClelland et al., 2007; Rothbart et al., 2003). The extant literature on self-regulation suggests that there are two main components through which this construct develops during the preschool years: executive functions and effortful control (Diamond, 2013; 2014; Kiss et al., 2014; Logue & Gould, 2014; Miyake et al., 2000; Moran et al., 2013). Recent studies have introduced the concepts of hot and cool regulation to describe the different processes that take place in the development of self-regulation. Hot and cool regulation processes seem to map onto the characteristics of effortful control and executive functions respectively, and could potentially be the bridge that unites these two separate approaches to bring the field to a better understanding of how the cognitive and emotional processes of self-regulation develop.

The focus of the present study was to test the validity of hot and cool tasks as concurrent measures of self-regulation and as predictive measures of school readiness within a low-income sample of preschoolers. We hypothesized that, a) for data collected in the fall (Time 1), Cool task performance would significantly correlate with measures
of academic achievement, whereas Hot task performance would significantly correlate with measures of socio-emotional competence, b) Hot and Cool tasks would capture fall to spring self-regulation growth, c) there would be gains in school readiness from fall to spring, and d) fall Hot and Cool tasks would distinctly predict socioemotional competence and academic achievement, respectively.

Supporting the first hypothesis, Cool task performance was moderately to highly correlated with measures of academic achievement, whereas Hot task performance was moderately to highly correlated with teacher ratings of socio-emotional competence. Fall performance on the Pencil Tap was positively correlated with performance on all subtests of the Woodcock Johnson, suggesting that across age, children with higher percent correct scores on the pencil tap performed better on Letter Word, Applied Problem, and Picture Vocabulary subtests. Specifically, Pencil Tap was highly correlated with the Applied Problems subtest, which is a measure of math performance. This result maps onto previous findings that executive functions are especially predictive of math performance (Verdine, Irwin, Golinkoff, & Hirsh-Pasek, 2014). For example, Verdine and colleagues assessed executive functions and spatial skills in a sample of preschoolers at age three, then tested their mathematic performance at age four. They found that executive functions uniquely predicted 43% of the variance in mathematic performance. This suggests that cool regulation, as previous studies suggest for executive functions, may be more associated with math-related processes.

Unlike the Pencil Tap task, Balance Beam performance was only correlated with the Letter Word subtest, and Toy Sort performance was only correlated with the Applied Problems subtest. These isolated correlations suggest that these two tasks may only tap
into a single process of executive functioning. However, the Toy Sort task did not correlate with the Balance Beam or Pencil Tap task, which suggests that Toy Sort may be a measure of compliance and does not fit under the Cool task category. Regarding Hot task performance, at least two of the three Hot tasks were correlated with all measures of socio-emotional competence as indexed by teacher ratings. This correlation pattern suggests that the regulation processes measured by these Hot tasks may in fact reflect processes of effortful control outlined in the literature, such as emotion regulation, and the behavioral inhibition and attention shifting required to deal with social and emotional demands (Gartstein et al., 2009; Murray & Kochanska, 2002).

In support of the second hypothesis, preschoolers’ Hot and Cool task performance improved from fall to spring, but this improvement differed by age group and depended on the task. With regard to hot regulation, results from the Toy Wrap and Snack Delay tasks suggest that four-year-olds had already mastered hot regulation in the fall, leaving no room for improvement in the spring. Three-year-olds on the other hand, showed significant improvement from fall to spring on all of the Hot tasks. These results suggest that hot regulation develops earlier in the preschool years, such that by age four, preschoolers are able regulate some emotional or arousing situations in order to comply with an adult’s request. However, results from the Toy Return task suggest that not all hot regulatory processes are mastered by age four. There were no age differences on this task, as both three- and four-year olds equally improved from fall to spring. The lack of age differences suggests that this task measures a dimension of hot regulation that both three- and four-year-olds are still developing. This difference in performance was not entirely unexpected, given that, unlike the Toy Wrap and Snack Delay tasks where the
child must wait in order to receive gratification, the Toy Return task requires the child to give up gratification (the toy) in compliance with the adults’ request. Given what we know about effortful control processes or hot processes (Kim, 2012; Kiss et al., 2014; Moran et al., 2013), this task may require a greater level of inhibition (i.e., stop a dominant response such as playing with the toy), a greater level of attention shifting (i.e., attend other stimuli in order to stop thinking about the toy), and perhaps more complex emotion regulation strategies that require higher-order cognitive development.

With regard to cool regulation, a different pattern of improvement was observed. For the Pencil Tap and Toy Sort tasks, both age-groups improved from fall to spring, but four-year-olds outperformed three-year olds across waves. Unlike some of the Hot tasks where four-year-olds’ performance was at ceiling, all of the Cool tasks captured variability in their performance. These results suggest that cool regulation develops later in the preschool period, presumably after some hot regulatory processes have developed. Furthermore, results from the Balance Beam suggest that some cool regulation processes have not yet emerged at age three. For this task, four-year-olds improved from fall to spring, whereas three-year-olds performed poorly at both times.

Supporting the third hypothesis, there were gains in Academic Achievement and Socioemotional Competence, although not all measures of the latter reflected significant gains. In fact, the Social Competence subscale of the Social Competence and Behavioral Evaluation (SCBE) was the only measure to reflect social gains from fall to spring. Additionally, four-year-olds were rated by their teachers as significantly more socially competent than three-year-olds at both times. This age difference maps onto the Hot task comparisons previously discussed, and the possibility that four-year-olds have mastered
some hot regulation processes, which allows them to engage in more socially accepted behavior.

Although we expected gains from all measures of socioemotional competence, the opposite was found for the Internalizing Behavior subscale. Internalizing behaviors actually increased from fall to spring for both age groups. These results may seem counterintuitive, given that Hot tasks did captured growth in hot regulation from fall to spring, which should in turn be reflected in less internalizing behaviors. However, it should be considered that internalizing behaviors were not measured through a direct assessment but with teacher ratings, and that although there was a significant increase in these behaviors, the ratings are rather low at both times. A possible explanation for the increase in reporting of internalizing behaviors may reside in the teacher-student relationship. It is possible that teachers were not very familiar with the students in the fall, making it difficult to identify these types of covert symptoms or behaviors. In the spring however, teachers were presumably more familiar with their students, allowing them to perceive more internalizing behaviors.

With regard to Academic Achievement, all Woodcock Johnson subtests reflected academic gains from fall to spring, supporting our hypothesis. Additionally, four-year-olds outperformed three-year-olds on all subtests. These results are in line with the Cool task comparisons, which suggested that both age groups were in the process of developing cool regulation, and therefore should be improving from fall to spring. These results are also in line with the rapid Prefrontal Cortex (PFC) development reported in the literature (Krikorian & Bartock, 1998; Luciana & Nelson, 1998), which supports that
both age groups are undergoing development, but that four-year-olds should outperform three-year-olds despite the small age difference.

The last hypothesis stated that Hot and Cool tasks would distinctly predict socioemotional competence and academic achievement respectively. This prediction was grounded on previous studies that found effortful control to be more predictive of socioemotional competence (Gusdorf et al., 2011; Kochanska et al., 1997), and executive functions to be more predictive of academic achievement (Alloway & Alloway, 2010; Borella et al., 2010). Contrary to our hypothesis, Hot tasks did not predict socioemotional competence above and beyond Cool tasks, and Cool tasks did not entirely predict academic achievement above and beyond Hot tasks. According to the regression results for the socioemotional measures, cool regulation seems to predict socioemotional competence in parallel with hot regulation, at least during the preschool years. According to the regression results for the academic subtests, Applied Problems was the only subtest predicted by Cool tasks above and beyond Hot tasks. These results are in line with previous findings that suggest executive functions and cool regulation processes are especially predictive of math performance (Verdine et al., 2014), which is the construct measured by the Applied Problems subtest. Neither of the other subtests (Letter Word and Picture Vocabulary) were predicted by Hot or Cool tasks. In summary, the predictive validity of Hot and Cool tasks does not seem to be as distinctive for Socioemotional Competence and Academic Achievement as that of effortful control and executive functions reported in the literature. A potential explanation for the lack of significant findings is that four-year-olds performed near ceiling on most of the hot tasks, and three-year-olds performed near floor in one out of the two Cool tasks included in the regression
model. The lack of variability could lead to the lack of prediction. Perhaps if most of the Hot tasks were as challenging for four-year-olds as the Toy Return task, we would have found distinctive predictions. In general, findings on self-regulation performance and the developmental trajectory of hot and cool regulation were in line with previous studies of preschoolers from middle- and high-income homes (Alloway & Alloway, 2010; Di Norcia et al., 2015; Luciana & Nelson 1998), which may suggest that at least within the present sample, preschoolers from low-income homes were not overtly different from their counterparts.

**Limitations**

As in all studies, there are limitations that should be mentioned and considered when interpreting the study’s results. One limitation was the lack of a comparison group, due to the small sample size (n = 18) of the Daycare group. Given this limitation, we were unable to compare self-regulation growth and school readiness gains between low- and middle-income groups. Additionally, the Head Start sample was also small, particularly because most analyses examined the data separately by age group. Furthermore, it was also a limitation that we did not have a true measure of socioeconomic status (SES), but rather a proxy variable that was based on the child’s enrollment status (Head Start vs. Daycare). Future studies should use a larger sample size, include low- and middle-income subsamples of comparable sizes, and use a continuous measure of SES.

Another limitation to consider is the short time-interval between assessments, which was around 6 months. It is possible that if given a longer time in-between assessments (e.g., a year), teacher ratings would have captured gains in socio-emotional...
competence. Future studies should employ a one- to two-year longitudinal design, with several data points rather than only two. Such a design would be able to capture development of hot regulation followed by emergence and refinement of cool regulation, and how these processes reflect on academic and socio-emotional gains over a longer period of time.

A third limitation relates to the fact that our measures of socio-emotional performance were based on teacher ratings only. Although children usually spend more time in school than anywhere else, teacher ratings of children’s socio-emotional performance are limited to the teachers’ observations and their memory for specific characteristics of the child or specific relevant events. Future studies should include more than one method for assessing socio-emotional competence, such as a direct assessment paired with teacher ratings.

**Implications**

Despite of the limitations previously discussed, the results of the present study have practical and theoretical implications. For example, the fact that four-year-olds performed at ceiling on most of the Hot tasks suggest that these tasks need to be adapted in order to capture variability among the older preschoolers. One way to adapt these tasks could be to increase the waiting time for delay of gratification, such as in the Snack Delay and Toy Wrap task. Increasing the waiting time means that preschoolers would have to not only trigger but also maintain hot regulation processes active for longer, which could make the task more challenging for four-year-olds, reducing ceiling effects. Additionally, the results suggest that the PSRA should be restructured in terms of categorization of tasks, given that some tasks may not entirely fit under the Hot or Cool
category (e.g., Toy Sort). Finally, it is worth mentioning that only one of the Cool tasks (Pencil Tap) was predictive of academic achievement, specifically math performance. Therefore, there is a need to include cool tasks that can potentially reflect dimensions of executive functioning that can predict not only math, but literacy and vocabulary performance as well.

The results of this study also carry theoretical implications for the extant literature on effortful control and executive functions, and how these components are thought to define self-regulation. For example, these two components have been studied separately throughout the years from two different approaches (temperament vs. cognitive). As a result, they are viewed as competing definitions of self-regulation. However, our results suggest that, at least for a low-income sample, hot and cool regulation seem to map onto effortful control and executive functions, suggesting that these components do not reflect the exact same construct, but rather different dimensions or processes underlying one construct. Additionally, through the years most research has focused on one component or the other, rather than studying how they are related or integrated. Our prediction results suggest that these two components and their processes may be on a continuum, rather than opposites or dichotomous. Furthermore, the developmental differences found in this study suggest that hot regulation, which develops earlier, may foster development of cool regulation; an idea that supports the proposition that hot and cool regulation define self-regulation as continuous rather than opposite processes.

Conclusions

Development of self-regulation is considered one of the most important systems by which children develop competence and are able to succeed in school (Masten &
Coatsworth, 1998). Hot and Cool tasks were examined as measures of self-regulation, in particular hot and cool regulation, and as predictive measures of school readiness. Results indicate that hot and cool regulation seem to map onto effortful control and executive functions respectively, suggesting they reflect similar processes. However, Hot and Cool tasks did not predict Socio-emotional Competence and Academic Achievement as expected, suggesting that hot and cool regulation may work in parallel or as a continuum to the prediction of these different aspects of school readiness. Additionally, fall to spring self-regulation comparisons suggest that hot regulation develops first, and that it could possibly foster the development of cool regulation, although this would require future research. In summary, results suggest that Hot and Cool tasks are valid measures of self-regulation, but that some modifications should be made to the Hot tasks in order to capture hot processes in older preschoolers. The predictive validity of these tasks however, requires further research using Hot task performance free from ceiling effects, and more than one method of assessing Socio-emotional Competence.
APPENDIX A: FALL AND SPRING SCHOOL READINESS PERFORMANCE ACROSS AGE

Fall and Spring School Readiness Performance Across Age.

<table>
<thead>
<tr>
<th>Tasks</th>
<th>N</th>
<th>M</th>
<th>SD</th>
<th>Min.</th>
<th>Max.</th>
<th>Skewness</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>F</td>
<td>S</td>
<td>F</td>
<td>S</td>
<td>F</td>
<td>S</td>
</tr>
<tr>
<td>Letter Word</td>
<td>56</td>
<td>59</td>
<td>7.1</td>
<td>8.6</td>
<td>5.6</td>
<td>6.1</td>
</tr>
<tr>
<td>Applied Problems</td>
<td>56</td>
<td>59</td>
<td>9.5</td>
<td>11.6</td>
<td>4.2</td>
<td>4.2</td>
</tr>
<tr>
<td>Picture Vocabulary</td>
<td>56</td>
<td>59</td>
<td>12.7</td>
<td>13.8</td>
<td>3.2</td>
<td>2.9</td>
</tr>
<tr>
<td>Social Competence</td>
<td>64</td>
<td>61</td>
<td>3.8</td>
<td>4.1</td>
<td>0.9</td>
<td>0.9</td>
</tr>
<tr>
<td>Internalizing Behaviors</td>
<td>64</td>
<td>61</td>
<td>1.5</td>
<td>1.6</td>
<td>0.4</td>
<td>0.5</td>
</tr>
<tr>
<td>Externalizing Behaviors</td>
<td>63</td>
<td>61</td>
<td>1.7</td>
<td>1.7</td>
<td>0.7</td>
<td>0.7</td>
</tr>
<tr>
<td>Emotion Regulation</td>
<td>64</td>
<td>61</td>
<td>3.6</td>
<td>3.6</td>
<td>0.5</td>
<td>0.5</td>
</tr>
<tr>
<td>Emotion Lability</td>
<td>64</td>
<td>61</td>
<td>1.9</td>
<td>1.9</td>
<td>0.4</td>
<td>0.5</td>
</tr>
<tr>
<td>N (listwise)</td>
<td>56</td>
<td>59</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*Note:* F = Fall data; S = Spring data.
APPENDIX B: HOT AND COOL INTERCORRELATIONS FOR FALL AND SPRING ACROSS AGE

**Hot and Cool Intercorrelations for Fall and Spring Across Age.**

<table>
<thead>
<tr>
<th></th>
<th>Balance Beam</th>
<th>Pencil Tap</th>
<th>Toy Sort</th>
<th>Toy Return</th>
<th>Toy Wrap</th>
<th>Snack Delay</th>
</tr>
</thead>
<tbody>
<tr>
<td>Balance Beam</td>
<td>-</td>
<td>.27*</td>
<td>-.02</td>
<td>.02</td>
<td>.18</td>
<td>.17</td>
</tr>
<tr>
<td>Pencil Tap</td>
<td>.27*</td>
<td>-</td>
<td>-.24**</td>
<td>-.02</td>
<td>.42**</td>
<td>.19</td>
</tr>
<tr>
<td>Toy Sort</td>
<td>.01</td>
<td>-.19</td>
<td>-</td>
<td>.18</td>
<td>-.28*</td>
<td>-.21</td>
</tr>
<tr>
<td>Toy Return</td>
<td>-.03</td>
<td>-.20</td>
<td>.00</td>
<td>-</td>
<td>.16</td>
<td>-.21</td>
</tr>
<tr>
<td>Toy Wrap</td>
<td>.06</td>
<td>.53**</td>
<td>-.10</td>
<td>-.24*</td>
<td>-</td>
<td>.20</td>
</tr>
<tr>
<td>Snack Delay</td>
<td>.16</td>
<td>.46**</td>
<td>-.14</td>
<td>-.37**</td>
<td>.60**</td>
<td>-</td>
</tr>
</tbody>
</table>

*Note: * $p < .05$; ** $p < .001$. Fall correlations are displayed in the bottom half of the table; Spring correlations are displayed in the top half.*
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