This article was downloaded by: [Rueda, M. Rosario]

On: 12 October 2010

Access details: Access Details: [subscription number 927989147]

Publisher Routledge

Informa Ltd Registered in England and Wales Registered Number: 1072954 Registered office: Mortimer House, 37-41 Mortimer Street, London W1T 3JH, UK

Early Education & Development

Publication details, including instructions for authors and subscription information:

<http://www.informaworld.com/smpp/title~content=t775653644>

Contributions of Attentional Control to Socioemotional and Academic Development

M. Rosario Rueda^a; Purificación Checa^a; Mary K. Rothbart^b

^a Departamento de Psicología Experimental y Fisiología del Comportamiento, Universidad de Granada, ^b Department of Psychology, University of Oregon,

Online publication date: 12 October 2010

To cite this Article Rueda, M. Rosario , Checa, Purificación and Rothbart, Mary K.(2010) 'Contributions of Attentional Control to Socioemotional and Academic Development', Early Education & Development, 21: 5, 744 – 764

To link to this Article: DOI: 10.1080/10409289.2010.510055

URL: <http://dx.doi.org/10.1080/10409289.2010.510055>

PLEASE SCROLL DOWN FOR ARTICLE

Full terms and conditions of use: <http://www.informaworld.com/terms-and-conditions-of-access.pdf>

This article may be used for research, teaching and private study purposes. Any substantial or systematic reproduction, re-distribution, re-selling, loan or sub-licensing, systematic supply or distribution in any form to anyone is expressly forbidden.

The publisher does not give any warranty express or implied or make any representation that the contents will be complete or accurate or up to date. The accuracy of any instructions, formulae and drug doses should be independently verified with primary sources. The publisher shall not be liable for any loss, actions, claims, proceedings, demand or costs or damages whatsoever or howsoever caused arising directly or indirectly in connection with or arising out of the use of this material.

Contributions of Attentional Control to Socioemotional and Academic Development

M. Rosario Rueda and Purificación Checa
*Departamento de Psicología Experimental y Fisiología
del Comportamiento
Universidad de Granada*

Mary K. Rothbart
*Department of Psychology
University of Oregon*

Research Findings: Part of the attention system of the brain is involved in the control of thoughts, emotions, and behavior. As attentional control develops, children are more able to control cognition and responses flexibly and to adjust their behavior in social interactions better. In this article, we discuss evidence from different levels of analysis (e.g., temperamental, cognitive, and neural) indicating that attentional control plays a central role in several factors related to schooling, including socioemotional adjustment and academic achievement. Connecting behavioral and cognitive levels of analysis with the function of a particular brain network opens the possibility of exploring other factors that might influence the efficiency of this self-regulatory system. Moreover, understanding the processes and factors influencing the development of attentional control has the potential to help parents and teachers in their effort to promote schooling success. *Practice or Policy:* We also discuss recent efforts to develop educational interventions aimed at enhancing children's attention skills.

Children differ greatly in their reactions to events in a variety of dimensions that include activity, emotion, and attention. One child is easily frustrated, has only a brief attention span, and tolerates only moderate levels of stimulating play, whereas another child enjoys even very rough play and seeks out exciting events. As children develop, they also show large differences in their capacity to regulate their reactions in accordance with socially learned norms, rules, or instructions. These reactions to the environment together with the mechanisms that regulate them constitute the child's temperament. *Temperament* refers to individual differences in reactivity and self-regulation assumed to have a constitutional basis (Rothbart & Derryberry, 1981). *Reactivity* refers to the excitability, responsivity, or arousability of the behavioral and physiological systems of an organism, whereas *self-regulation* refers to neural and behavioral processes that function to modulate reactivity. Distinguishing between reactive and self-regulative characteristics has been useful in thinking about development generally, in that much of immature behavior can be seen as reactive to immediate stimulus events and to endogenous changes in state. However, as self-regulatory systems develop, the individual becomes more able to control reactivity and adjust to norms or goals, even if they conflict with internal desires (Derryberry & Rothbart, 1997; Rothbart & Derryberry, 1981). When it comes to regulating behavior, individual differences in both emotional reactivity and attention skills are likely to play a role. Generally, low or moderate reactivity together with good self-regulative skill leads to better chances for appropriate socialization and school success. Affective contributions to schooling and achievement have recently been discussed by Rothbart (in press) elsewhere. In this article, we focus on the contributions of attention to socioemotional and academic development.

We believe that mechanisms of attention are central to the development of self-regulatory skills. The study of attention and self-regulation arose from different research traditions. Attention has been a prolific area in experimental psychology since the second half of the 20th century and is currently being studied at many levels in cognitive neuroscience. Self-regulation, most commonly with respect to emotional control, has also been a central topic in developmental psychology and in child and family studies. In their volume *Attention in Early Development*, Ruff and Rothbart (1996) viewed attention as "part of the larger construct of self-regulation—the ability to modulate behavior according to the cognitive, emotional and social demands of specific situations" (p. 7). Since then, efforts have been made to integrate these two concepts and to investigate the role individual differences in attentional efficiency play in the development of successful self-regulation (Posner & Rothbart, 1998, 2000, 2007; Rueda, Posner, & Rothbart, 2004). In this article, we discuss the importance of the attention system involved in self-regulation for processes of socioemotional adjustment and schooling across development.

EXECUTIVE ATTENTION, EFFORTFUL CONTROL, AND SELF-REGULATION

The control of cognition and action has been a matter of great interest in cognitive psychology (Posner & Snyder, 1975). Researchers in this field are interested in the cognitive processes and mechanisms underlying self-regulation. The control of thoughts, emotions, and responses has been linked to mechanisms of attention from the earliest theoretical models (James, 1890). In Posner's neurocognitive model, this control is attributed to the executive attention network, a neurocognitive system involving the mechanisms for consciously monitoring and resolving conflict among thoughts, feelings, and responses. Activation of this network is related to coordinating action in novel or dangerous situations, detecting and correcting errors, and overcoming habitual (or automatic) responses (Posner & DiGirolamo, 1998; Posner & Petersen, 1990).

Imaging studies conducted in the past years with adults have shown that the brain network associated with executive attention includes a midline brain structure, the anterior cingulate, and various regions of the lateral prefrontal cortex (Fan, Flombaum, McCandliss, Thomas, & Posner, 2003; Fan, McCandliss, Fossella, Flombaum, & Posner, 2005). This brain network appears to carry out control operations that facilitate or inhibit the functions of other networks, providing a neural basis for self-regulation (Posner & Rothbart, 1998; Posner, Rothbart, Sheese, & Tang, 2007). The regulatory function of attention involves modulation of sensory systems as well as regions involved in the processing of more elaborate information, such as language, memory, and the emotions. For instance, the dorsal portion of the anterior cingulate cortex (ACC) is highly interconnected with lateral frontal and parietal structures and becomes active when a task requires selecting from among conflicting alternatives (Botvinick, Braver, Barch, Carter, & Cohen, 2001; Bush, Luu, & Posner, 2000). More ventral areas of the ACC in conjunction with other limbic structures (e.g., the amygdala) provide a basis for the regulation of emotion (Drevets & Raichle, 1998; Ochsner & Gross, 2005).

Studies of temperament have attempted to understand the role of individual differences in the ability to self-regulate at the behavioral level. Research in the past years has come to identify three broad dimensions that characterize temperament during childhood and adolescence (Rothbart, 2007; Rothbart & Bates, 2006): extraversion/surgency, negative affect, and effortful control (EC). The first two dimensions describe individual differences in approach and defensive reactivity, respectively. The third dimension describes individual differences in attentional control and the flexible regulation of behavior, such as choosing a particular action under conflicting conditions, detecting errors, and planning (Rothbart & Rueda, 2005). Thus, the behavioral characteristics within the concept of EC constitute a major form of self-regulation (Rothbart, Ellis, & Posner, 2004; Rothbart & Rueda, 2005).

EC is often measured using temperament questionnaires. These are made up of questions about people's reactions to everyday situations on a variety of behavioral dimensions. The dimensions that load onto the general factor of EC are attention control (including control over focusing and shifting attention), inhibitory control, perceptual sensitivity, and low-intensity pleasure. These are distinct from those loading onto the factors of Extraversion/Surgency (activity level, positive anticipation, high-intensity pleasure/sensation seeking, impulsivity, smiling and laughter, and a negative loading from shyness) and Negative Emotionality (shyness, discomfort, fear, anger/frustration, sadness, and a negative loading from soothability/falling reactivity; Rothbart, 2007).

Early theoretical models of temperament emphasized how people are moved by positive and negative emotions or level of arousal (e.g., Eysenck, 1990). In our view, the concept of EC is central to the theory of temperament in that we are not always at the mercy of affect. Using EC, children become progressively more able to flexibly approach situations they fear and inhibit actions they desire. The efficiency of control, however, will depend on both the strength of the emotional processes against which effort is exerted (Rothbart, Derryberry, & Hershey, 2000) and the effectiveness of neurocognitive and behavioral mechanisms of control (Rueda, Posner & Rothbart, 2004).

We have argued that the executive attention network is the neural substrate supporting EC (Posner & Rothbart, 1998, 2007; Rothbart & Rueda, 2005; Rueda, Posner, & Rothbart, 2004). We view executive attention and EC as concepts representing different levels of analysis of the ability to exercise control over one's behavior (Rothbart & Rueda, 2005; Rueda, Posner, & Rothbart, 2004). Executive attention is a construct emerging from the neurocognitive literature and is linked to the control of cognition and cognitive flexibility, whereas EC is a concept developed within the literature on temperament related to the regulation of reactivity systems associated with positive/approaching and negative/avoiding responses.

MARKER TASKS OF THE EXECUTIVE ATTENTION NETWORK

Over the past years, we have used model tasks to assess the executive attention capacities likely to underlie EC (Posner & Rothbart, 1998; Rothbart, Ellis, Rueda, & Posner, 2003; Rueda, Posner, & Rothbart, 2005). Monitoring and resolving conflict between incompatible responses requires voluntary and attentive control of action and, as discussed earlier, is considered a function of executive attention. Cognitive tasks involving conflict have been extensively used to measure the efficiency with which control of action is exerted (Botvinick et al., 2001; Posner & DiGirolamo, 1998).

A basic measure of conflict interference is provided by the Stroop task (Stroop, 1935). The original form of this task required subjects to look at words denoting colors and to report the color of ink the words were written in instead of reading them. Presenting incongruent perceptual and semantic information (e.g., the word *blue* written with red ink) induces conflict and produces a delay in response time compared to when the two sources of information match. It is known from adult brain imaging studies that Stroop tasks activate the ACC. A meta-analysis of imaging studies showed that the dorsal section of the ACC was activated in response to cognitive conflict tasks such as variants of the Stroop task, whereas the ventral section appeared to be activated mostly by emotional tasks and emotional states (Bush et al., 2000). The two divisions of the ACC also seem to interact in a mutually exclusive way. For instance, when the cognitive division is activated, the affective division tends to be deactivated and vice versa, suggesting the possibility of reciprocal effortful and emotional controls of attention (Drevets & Raichle, 1998).

The flanker task is another widely used method of studying conflict resolution. In this task, the target is surrounded by irrelevant stimulation that can either match with or conflict with the response required by the target (Eriksen & Eriksen, 1974). As with the Stroop task, resolving interference from distracting incongruent stimulation delays reaction times and activates the dorsal portion of the ACC together with other regions of the lateral prefrontal cortex (Botvinick, Nystrom, Fissell, Carter, & Cohen, 1999; Fan et al., 2003).

When researchers know the kinds of tasks that activate a given brain region, they can adapt them to children as marker tasks. It is then possible to trace the development of function in the brain areas through children's performance on the tasks. With young children, somewhat easier versions of adult conflict tasks must be used. One example of these is the spatial conflict task (Gerardi-Caulton, 2000). In this task, a child sits in front of two response keys, one located to the child's left and one to the right. Each key displays a picture, and on every trial a picture identical to one member of the pair appears on either the left or right side of the screen. The child's job is to respond to the identity of the stimulus regardless of its spatial compatibility with the matching response key (see Figure 1).

Several years ago we developed a child-friendly version of the flanker task in which rows of fish pointing left and right were used as stimuli (Rueda, Fan, et al., 2004). Instructions are for children to help feed the fish in the middle, or simply make it happy, by pressing a key corresponding to the direction it points. The middle fish is surrounded by fish that point in either the same direction (congruent trials) or the opposite direction (incongruent trials) than the middle one (see Figure 1). After the response, an elaborate feedback involving animation of the fish is provided in order to keep the child engaged on the task. We have used this task to trace the development of the executive attention network from early to late childhood (Rueda, Rothbart, et al., 2005; Rueda, Posner, Rothbart, & Davis-Stober, 2004). We found a steady increase in the efficiency to resolve conflict between 4 and 7 years of age but little change between 7-year-olds and older children or adults (Rueda, Posner, et al.,

FIGURE 1 Examples of conflict tasks from the adult literature adapted for use with children. (a) General instructions and (b) pictures depicting congruent and incongruent trials are presented for the spatial conflict and flanker tasks.

FIGURE 2 Development of conflict resolution during childhood. The graph depicts the conflict effect between age 2 and age 10, and adulthood. Conflict is calculated as the subtraction of incongruent from congruent trials, using the mean of either reaction time (RT; in ms) or percentage of errors. Data from age 2 to 3 (left of the dotted line) were collected using the spatial conflict task; data from age 4 on were collected using the fish flanker task. Data from Rueda, Posner, et al. (2005).

2005 ; see Figure 2). Using the child version of the flanker task together with event-related potentials (ERPs), we have also studied the neural mechanisms underlying the maturation of the executive attention network from 4 to 7 years of age. Often, when a response is required to the presentation of a stimulus, a negative wave is observed over frontal leads around 200 to 300 ms after presentation of the target (N200). The amplitude of the N200 is modulated by conflict, indicating greater activation of frontal structures, such as the ACC, in conditions involving conflict (Kopp, Rist, & Mattler, 1996; van Veen & Carter, 2002). In children, the modulation of the negative deflection by conflict appears later, is sustained over a longer period, and has a more anterior distribution compared to in adults (Rueda, Posner, Rothbart, et al., 2004; Rueda, Rothbart, McCandliss, Saccomanno, & Posner, 2005; see Figure 3). This is consistent with the greater difficulty in resolving conflict shown by children in reaction time measures and suggests that children may engage additional frontal structures over longer time to resolve conflict compared to adults.

FIGURE 3 Development of conflict-related brain activation as assessed with event-related potentials (ERPs). (a) A 4-year-old girl performs a conflict task while her brain activation is being recorded with a high-density electroencephalographic (EEG) system. (b) Electrode location (AFz and Fcz in the 10-10 international electrode position system) in the 128-channel net used for EEG registration. (c) Target-locked ERPs across ages for congruent and incongruent trials. (d) Topographic maps depicting the distribution of the conflict effect (the difference between congruent and incongruent trials) on the scalp at a particular time after presentation of the target. Data from Abundis, Checa, Pozuelos, & Rueda (submitted).

Another important form of self-regulation is related to the ability to detect and correct self-made errors. Using the spatial conflict task, we showed that, by age 3, children exhibit longer reaction times following an error than following trials that they had responded correctly to, indicating that they notice errors and try to correct them (Rothbart et al., 2003). Depending on the difficulty of the task, the slowing following an error may appear later, but we believe there is an important development of this capacity during the preschool years (Jones, Rothbart, & Posner, 2003). Detection and monitoring of errors has also been studied using ERPs (Gehring, Gross, Coles, Meyer, & Donchin, 1993). A large negative deflection over midline frontal channels, called the error-related negativity (ERN), is often observed about 100 ms after the commission of an error. There is evidence that this post-response signal originates in the ACC (Dehaene, Posner, & Tucker, 1994; Luu, Tucker, Derryberry, Reed, & Poulsen, 2003). The ERN thus provides a means of examining the emergence of this cingulate function during infancy and childhood.

Studying the emergence of executive attention is important because cognitive measures of conflict resolution in laboratory tasks have been linked to aspects of children's EC in naturalistic settings. Children who are relatively less affected by conflict also receive higher parental ratings of temperamental EC and higher scores on laboratory measures of inhibitory control (Gerardi-Caulton, 2000; Gonzalez, Fuentes, Carranza, & Estevez, 2001; Rothbart et al., 2003; Simonds, Kieras, Rueda, & Rothbart, 2007). Knowing the neural substrates for EC provides a tool for examining which aspects of this form of self-regulation are subject to genetic influence, as well as how the functioning of this system may be influenced by experience.

ATTENTIONAL CONTROL AND SOCIOEMOTIONAL DEVELOPMENT

Both reactive and regulative systems, as well as the interactions between them, are involved in the socialization of children and their capacity for socioemotional regulation. One piece of evidence for this comes from studies showing that, after other cognitive and social risk factors are controlled, EC during childhood is negatively associated with the incidence of externalizing behavioral problems, which are characterized by high levels of aggression and impulsivity (Olson, Sameroff, Kerr, Lopez, & Wellman, 2005; Valiente et al., 2003). In addition, preadolescents with and without behavioral problems appear to have different temperamental profiles. Evidence indicates that low EC constitutes a substrate of the presence of behavioral problems. Individuals exhibiting externalizing problems show higher scores on extraversion/surgency and frustration and lower rates of EC, whereas individuals showing internalizing problems are high on fear and shyness and moderately

low on EC (Oldehinkel, Hartman, De Winter, Veenstra, & Ormel, 2004). Other studies have also shown that both mother- and self-reported low EC together with poor efficiency of executive attention predict behavior problems during adolescence (Ellis, Rothbart, & Posner, 2004).

Mechanisms of self-regulation related to activation of the executive attention network are likely to play a role in the relation between low EC and poor socialization. In a study conducted with a flanker task and ERPs, it was shown that children who committed more errors on incongruent trials showed smaller amplitudes in the error monitoring wave, the ERN. This result suggests less sensitivity of the brains of these children to the commission of errors. Also, the amplitude of the ERN was predicted by individual differences in social behavior, in that children with poorer social sensitivity as assessed by a self-report personality questionnaire showed ERNs of smaller amplitude (Santesso, Segalowitz, & Schmidt, 2005). These results are consistent with imaging studies showing that adults with socialization abnormalities (e.g., psychopathy) have deficient activation of limbic structures, including the anterior and posterior cingulate cortex and amygdala, in response to affective stimulation (Kiehl et al., 2001). All of these data suggest that relatively unsocialized individuals have greater difficulty experiencing or appreciating the emotional significance of errors and other unfavorable outcomes because of weaker responses of their limbic structures.

However, empathy appears to show a positive relation with the amplitude of the ERN (Santesso & Segalowitz, 2009). Children high in EC also appear to be high in empathy and guilt/shame and low in aggressiveness (Rothbart, Ahadi, & Hershey, 1994). Eisenberg, Fabes, Nyman, Bernzweig, and Pinuelas (1994) have also found that 4- to 6-year-old boys with good attentional control tend to deal with anger by using nonhostile verbal methods rather than overt aggressive methods. Displaying empathy toward others requires interpreting their signals of distress or pleasure. In our view, EC may support empathy by allowing attention to the thoughts and feelings of others, and it also helps one regulate one's own distress in order not to become overwhelmed by it and in order to enable helping behavior.

Similarly, guilt/shame in 6- to 7-year-olds is positively related to EC and to negative affectivity (Rothbart et al., 1994). Negative affectivity may contribute to guilt by providing strong internal cues of discomfort, increasing the likelihood that the cause of these feelings will be attributed to an internal conscience rather than external reward or coercion (Dienstbier, 1984; Kochanska, 1993). EC may contribute further by providing the attentional flexibility needed to notice these feelings and relate them to feelings of responsibility for one's own specific actions and their negative consequences for another person (Derryberry & Reed, 1994).

What is considered moral or socially acceptable greatly depends upon the cultural context and needs to be learned during development. Kochanska and colleagues have shown that EC plays an important role in the development of conscience (Kochanska & Aksan, 2006; Kochanska, Murray, & Coy, 1997). The

internalization of moral principles also appears to be facilitated in fearful preschool-age children, especially when their mothers use gentle discipline (Kochanska, 1997), and internalized control is greater in children high in EC (Fowles & Kochanska, 2000; Kochanska, Murray, & Harlan, 2000).

In a study conducted at the University of Oregon, we observed that in the course of development children are increasingly able to accommodate to social norms and that this capacity is related to the efficiency of attentional mechanisms. In this study, children were given an undesired gift while their emotional reaction was being videotaped. The amount of smiling in response to the undesired gift increased with age. However, greater ability to accommodate to the social norm of smiling when receiving a gift was related to less interference due to distracting stimulation while performing the child version of the flanker task (Simonds et al., 2007). This evidence indicates that greater efficiency of mechanisms of control provides the attentional flexibility required to link negative affect (feelings of disappointment), internalized social norms, and action in everyday life situations. Another piece of evidence that leads us to the same conclusion is that efficiency of executive attention, in this case measured with the adult version of the flanker task (the adult Attention Network Test [ANT]; see Fan, McCandliss, Sommer, Raz, & Posner, 2002), as well as EC are related to peer-reported measures of antisocial behavior in the classroom and increased risk for social rejection. Larger flanker interference and lower EC was associated with greater disturbing behavior in the classroom and increased rates of peer rejection in a group of 12-year-old children (Checa, Rodriguez-Bailon, & Rueda, 2008).

Individual differences in EC are also related to some aspects of metacognitive knowledge, such as theory of mind (i.e., knowing that people's behavior is guided by their beliefs, desires, and other mental states; Carlson & Moses, 2001). The relation between measures of inhibitory control and theory of mind holds after controlling for other executive functions such as working memory or planning (Carlson, Moses, & Breton, 2002; Carlson, Moses, & Claxton, 2004). Because of the importance of understanding the feelings and desires of others in the socialization process, this ability is likely to play a part in socioemotional development and the degree of successful socialization.

All together, these data suggest that more efficient mechanisms of executive attention, such as interference inhibition and conflict resolution, lead to a greater ability to exert regulation at the cognitive, emotional, and behavioral levels, which in turn results in better chances of successful socialization.

In terms of neural systems, evidence points to the central role of the limbic system in the process of socioemotional regulation. Neuropsychological and imaging work with adults has shown that human faces displaying negative affect (e.g., fear and sadness) activate the amygdala (Davidson & Irwin, 1999). When increasing the intensity of distress signals in the faces, this activation is accompanied by activity in the anterior cingulate as part of the executive attention network (R. J. R.

Blair, Morris, Frith, Perrett, & Dolan, 1999). It seems likely that ACC activity represents the basis for attention to the distress of others. In children, a strongly reactive amygdala would provide the signals of distress that would easily allow empathic feelings toward others, leading to children who might be relatively easy to socialize. In the absence of this form of control, development of the cingulate would allow for appropriate attention to signals of distress in others.

ATTENTIONAL CONTROL AND SCHOOLING

We have argued that variations in reactivity and attentional control affect children's socioemotional adjustment processes. These processes in turn influence aspects of social development such as self-esteem and relationships with peers, parents, and teachers (Sanson, Hemphill, & Smart, 2004). In turn, these developments are very likely to affect children's adjustment to the requirements and challenges of the educational setting. For instance, there is evidence that peer rejection leads to decreases in classroom participation and to lower rates of achievement in childhood (Buhs, Ladd, & Herald, 2006).

Children's attention skills are also likely to affect their willingness to explore and learn as well as their level of discouragement and frustration at school. Some evidence indicates that children's regulatory strategies, such as self-distraction and attention, are associated with adjustment to the school context (Raver, Blackburn, Bancroft, & Torp, 1999). Eisenberg and colleagues (1997) found an association between teachers' and parents' reports of elementary schoolchildren's attentional control and peer nominations for social status. Negative emotionality and low EC have also been consistently linked to problems in adjustment at school from a young age (Nelson, Martin, Hodge, Havill, & Kamphaus, 1999). In a study conducted in Spain with 12-year-olds, we found a consistent negative relation between peer social rejection and schooling competence, with better socially adjusted children obtaining higher grades and showing better schooling skills (Checa et al., 2008). Teacher-rated higher levels of aggression and anxiety in kindergarten are also related to poorer achievement through a lack of cognitive self-control in school tasks (Normandeau & Guay, 1998). In addition, measures of EC in preschool children show a positive association with academic outcomes, especially those related to arithmetic reasoning (C. Blair & Razza, 2007). The relationship between school maladjustment and poor academics thus seems to be consistently found across ages and cultures. Some authors have proposed that positive social relationships at school constitute the primary factor promoting school competence (Mashburn & Pianta, 2006). However, in the Spanish study, we found that individual differences in EC mediated the relationship between peer-reported rates of successful socialization at school. Both academic achievement and schooling skills are important for school success, such as rule following, tolerating frustration, and

understanding the role of the students in the classroom, were influenced by EC (Checa et al., 2008).

The role of attention in cognitive flexibility and regulation suggests that this function would also contribute to academic outcomes, particularly in subjects requiring management of memory representations and reasoning processes, such as mathematics. Indeed, attention has emerged as a potentially robust predictor of arithmetic skills (Fuchs et al., 2005; Russell & Ginsburg, 1984). Passolunghi and collaborators have shown that children's arithmetic performance is related to the ability to control irrelevant information. In one of their studies, they selected fourth graders according to their ability to solve word problems in arithmetic and followed them longitudinally for a 2-year period. Although poor problem solvers were able to identify relevant information, they remembered less relevant and more irrelevant information about the arithmetic questions than good problem solvers (Passolunghi, Cornoldi, & De Liberto, 1999). This finding indicates that children exhibiting poorer arithmetic performance have greater difficulty inhibiting irrelevant information compared to better performers. Other measures tapping the executive attention network, such as Stroop-like measures of interference and performance on inhibitory control tasks, have shown a consistent relationship with arithmetic competency (Blair & Razza, 2007; Bull & Scerif, 2001; Espy et al., 2004). Despite the substantial overlap between executive functions and general intelligence (J. Duncan & Owen, 2000), the relationship between executive attention and arithmetic performance appears to be independent of intelligence (Blair & Razza, 2007). Using the arrow flanker task, we have also reported an association between degree of interference by distracting stimulation and lower grades in math (Checa et al., 2008).

In a recent study we further explored the role of brain mechanisms of executive attention in the relationship between interference control and schooling skills and achievement. We used ERPs to assess brain function during performance of the flanker task by a group of 12-year-olds. As mentioned earlier, the amplitude of the frontal effect related to conflict resolution in incongruent trials is considered an index of the efficiency of the executive attention network. It is modulated by maturation, in that younger children exhibit larger and more sustained effects (see Figure 3). We found that the amplitude of this ERP component significantly predicted grades in mathematics as well as rule-following skills after controlling for IQ and EC. Larger conflict effects predicted poorer achievement and lower schooling skills (Checa & Rueda, under review).

The role of attentional control in school performance and reasoning might also have to do with the anatomical overlap between the executive attention network and brain areas related to general intelligence and a wide range of cognitive demands related to the control of cognition (Duncan & Owen, 2000). Lateral frontal regions of the brain considered to be part of the executive attention network are activated by marker tasks of general intelligence (Duncan et al., 2000). In our view,

efficiency of this brain network results in more successful acquisition and application of knowledge taught in the school, especially in those subjects involving complex reasoning, such as mathematics.

EDUCATIONAL INTERVENTIONS

We argued at the beginning of this article that individual differences in children's temperament have a constitutional basis. By *constitutional* we refer to the relatively enduring biological makeup of the organism, which is influenced over time by genes and maturation but also experience. As such, we consider that temperament both *influences* and *is influenced by* the experience of the individual and that this might apply just as well to reactivity processes as to systems of self-regulation.

Since the sequencing of the human genome in the year 2001 (Venter et al., 2001), many studies have shown that genes influence individuals' attention capacity (see Posner, Rothbart, & Sheese, 2007). Data of this sort could wrongly lead to the impression that attention is not susceptible to experience and cannot be enhanced by intervention. However, this conclusion would greatly contradict evidence on the extraordinarily plastic capacity of the human nervous system, especially during development (see Posner & Rothbart, 2007). There is some evidence suggesting that susceptibility to the environment might even be embedded in genetic endowment, since some genetic polymorphisms, often under positive selection, appear to make children more susceptible to environmental factors such as parenting (Sheese, Voelker, Rothbart, & Posner, 2007).

Much evidence has been provided in the past years in favor of the susceptibility of systems of self-regulation to the influence of experience. One piece of evidence comes from studies showing the vulnerability of attention to environmental aspects such as parenting and socioeconomic status (Bornstein & Bradley, 2003). Children whose parents have lower levels of education, for example, have more difficulty selecting out irrelevant information, as shown by ERPs, than children with highly educated parents (Stevens, Lauinger, & Neville, 2009). Low income also appears to be associated with children's higher levels of fear and irritability and lower EC, as well as higher levels of rejection by parents and inconsistent discipline (Lengua, 2006).

On a more positive note, several studies have shown that different intervention methods lead to significant improvements in attentional efficiency. Several years ago, we designed a set of computer exercises aimed at training attention and tested a 5-day training intervention with children between 4 and 6 years of age (Rueda, Rothbart, et al., 2005). The period of 4 to 6 is a time of major development of executive attention. Before and after training, the children performed the child ANT while their brain activation was recorded with an EEG system. Children in the intervention group showed clear evidence of improvement in the executive attention

network following training in comparison with the control group, who viewed interactive videos matched to the duration of the intervention. The frontal negative ERP typically observed in conflict tasks showed a more adult-like pattern (shorter delay and progressively more posterior scalp distribution) in trained children compared to controls, suggesting that the training had altered the brain mechanisms of conflict resolution in a positive direction. The beneficial effect of training attention also transferred to nontrained measures of fluid intelligence. Recently, a replication of this study was carried out with a sample of 37 five-year-olds in a Spanish preschool. In this study, the benefits of training in brain activation and intelligence were replicated, and the trained group was shown to maintain these training effects 2 months afterward without further training (Rueda, Checa, & Santonja, 2008). Moreover, the training of attention also showed a modest positive effect on performance of affective regulation tasks, such as delay of gratification and the children's gambling task.

Consistent with our results, other studies have shown beneficial effects of cognitive training on attention and other forms of executive functions during development. For instance, auditory selective attention was improved by training with a computerized program designed to promote oral language skills in both language-impaired and typically developing children (Stevens, Fanning, Coch, Sanders, & Neville, 2008). Klingberg and colleagues have shown that working memory can be enhanced by training and that the effect shows some degree of transfer to aspects of attention (Thorell, Lindqvist, Nutley, Bohlin, & Klingberg, 2009). The Klingberg group has also shown evidence that training produces changes at various levels of brain function, such as activation (Olesen, Westerberg, & Klingberg, 2004), and in the density of dopamine receptors (McNab et al., 2009) of areas of the cerebral cortex involved in the trained function.

There is also some evidence that curricular interventions directly carried out in the classroom can lead to improvements in children's cognitive control. Diamond, Barnett, Thomas, and Munro (2007) tested the influence of a specific curriculum on preschoolers' control abilities and found beneficial effects as measured by various conflict tasks. In evaluations of early education programs in the United States, it was found that school attendance and socioemotional adjustment improved in children who were trained in Head Start (G. J. Duncan et al., 2007). Although Head Start does not specifically involve attention training, the program likely influences the ability to regulate thoughts and behavior through the forms of instruction it provides.

A somewhat indirect but probably not less beneficial form of fostering attention in school could be provided by multilingual education. Growing evidence indicates that bilingual individuals perform better on executive attention tasks than monolinguals (Bialystok, 1999; Costa, Hernandez, & Sebastian-Galles, 2008). The idea is that people who use multiple languages on a regular basis might train executive attention because of the need to suppress one language while using the other.

Although all of this evidence shows promising results for the effectiveness of interventions and in particular educational methods to promote self-regulation, questions on various aspects of training remain to be answered. In future studies, it will be important to address questions such as whether genetic variation and other constitutionally based variables influence the extent to which the executive attention network can be modified by experience, and whether there are limits to the ages at which training can be effective. In addition, further research will be needed to examine whether the beneficial effects of these interventions also affect temperament and academic performance and transfer to abilities relevant for schooling competence, such as socioemotional regulation.

CONCLUSIONS

We have presented evidence that individual differences in attentional control and self-regulation play an important role in socioemotional development and academic success. Figure 4 presents an overview of the neurocognitive and temperamental constructs considered in this article and their hypothesized relationship to several dimensions of school competence.

In a meta-analysis of six longitudinal studies conducted in the United States, Britain, and Canada, it was shown that attention skills measured prior to school entry were a key factor for school readiness because of their power to predict later success in school (G. J. Duncan et al., 2007). In this article, we have presented arguments that may help explain the role of attention for school readiness.

Functioning of the executive attention network determines the efficiency of one's control over cognition, emotion, and behavior. Convergent evidence from multiple levels of analysis indicates that attentional control is central to a variety of skills related to social adjustment and academic performance. Many of these appear to be interrelated. Executive attention and EC predict aspects of school competence, such as academic achievement and social adjustment in the classroom. In turn, better adjusted children are the ones obtaining better grades at school and showing better scores in skills important for school competence. We have also presented evidence indicating that the relationship between social maladjustment and poorer schooling outcomes is mediated by children's ability to regulate their own behavior.

Connecting behavioral and cognitive levels of analysis with the functioning of a particular neural network is important because it opens the possibility of exploring other factors that might influence the efficacy of self-regulation, such as neurochemistry and genetics. A deeper understanding of the biological mechanisms implicated in attentional control will be important in preventing and remediating pathologies involving attention. Moreover, emphasizing the central role of systems of self-regulation offers guidance for designing interventions and curricula to aid

FIGURE 4 Model depicting the relationships between executive attention, effortful control, and variables of schooling competence.

children in developing cognitive and behavioral strategies of control, increasing the likelihood of successful schooling.

ACKNOWLEDGMENTS

This work was supported by grants from the Spanish Ministry of Science and Innovation to M. Rosario Rueda (reference: SEJ2005-01473 and PSI2008-02955).

REFERENCES

- Abundis, A., Checa, P., Pozuelos, J. P., & Rueda, M. R. (under review). *Neural basis of the development of attention networks: An ERPs study*. Manuscript submitted for publication.
- Bialystok, E. (1999). Cognitive complexity and attentional control in the bilingual mind. *Child Development*, 70, 636–644.
- Blair, C., & Razza, R. P. (2007). Relating effortful control, executive function, and false belief understanding to emerging math and literacy ability in kindergarten. *Child Development*, 78, 647–663.

- Blair, R. J. R., Morris, J. S., Frith, C. C., Perrett, D. I., & Dolan, R. J. (1999). Dissociable neural responses to facial expressions of sadness and anger. *Brain*, 122, 883–893.
- Bornstein, M. H., & Bradley, R. H. (2003). *Socioeconomic status, parenting, and child development*. Mahwah, NJ: Erlbaum.
- Botvinick, M. M., Braver, T. S., Barch, D. M., Carter, C. S., & Cohen, J. D. (2001). Conflict monitoring and cognitive control. *Psychological Review*, 108, 624–652.
- Botvinick, M., Nystrom, L. E., Fissell, K., Carter, C. S., & Cohen, J. D. (1999, November 11). Conflict monitoring versus selection-for-action in anterior cingulate cortex. *Nature*, 402, 179–181.
- Buhs, E. S., Ladd, G. W., & Herald, S. L. (2006). Peer exclusion and victimization: Processes that mediate the relation between peer group rejection and children's classroom engagement and achievement? *Journal of Educational Psychology*, 98, 1–13.
- Bull, R., & Scerif, G. (2001). Executive functioning as a predictor of children's mathematics ability: Inhibition, switching, and working memory. *Developmental Neuropsychology*, 19, 273–293.
- Bush, G., Luu, P., & Posner, M. I. (2000). Cognitive and emotional influences in anterior cingulate cortex. *Trends in Cognitive Sciences*, 4(6), 215–222.
- Carlson, S. M., & Moses, L. J. (2001). Individual differences in inhibitory control and children's theory of mind. *Child Development*, 72, 1032–1053.
- Carlson, S. M., Moses, L. J., & Breton, C. (2002). How specific is the relation between executive function and theory of mind? Contributions of inhibitory control and working memory. *Infant and Child Development*, 11(2), 73–92.
- Carlson, S. M., Moses, L. J., & Claxton, L. J. (2004). Individual differences in executive functioning and theory of mind: An investigation of inhibitory control and planning ability. *Journal of Experimental Child Psychology*, 87, 299–319.
- Checa, P., Rodriguez-Bailon, R., & Rueda, M. R. (2008). Neurocognitive and temperamental systems of self-regulation and early adolescents' school competence. *Mind, Brain and Education*, 2(4), 177–187.
- Checa, P., & Rueda, M. R. (under review). *Behavioral and brain measures of attentional control predict schooling competence in early adolescence*. Manuscript submitted for publication.
- Costa, A., Hernandez, M., & Sebastian-Galles, N. (2008). Bilingualism aids conflict resolution: Evidence from the ANT task. *Cognition*, 106(1), 59–86.
- Davidson, R. J., & Irwin, W. (1999). The functional neuroanatomy of emotion and affective style. *Trends in Cognitive Sciences*, 3(1), 11–21.
- Dehaene, S., Posner, M. I., & Tucker, D. M. (1994). Localization of a neural system for error detection and compensation. *Psychological Science*, 5, 303–305.
- Derryberry, D., & Reed, M. A. (1994). Temperament and attention: Orienting toward and away from positive and negative signals. *Journal of Personality and Social Psychology*, 66, 1128–1139.
- Derryberry, D., & Rothbart, M. K. (1997). Reactive and effortful processes in the organization of temperament. *Development and Psychopathology*, 9, 633–652.
- Diamond, A., Barnett, W. S., Thomas, J., & Munro, S. (2007, November 30). Preschool program improves cognitive control. *Science*, 318, 1387–1388.
- Dienstbier, R. A. (1984). The role of emotion in moral socialization. In C. E. Izard, J. Kagan, & R. B. Zajonc (Eds.), *Emotions, cognition, and behavior* (pp. 484–518). New York: Cambridge University Press.
- Drevets, W. C., & Raichle, M. E. (1998). Reciprocal suppression of regional cerebral blood flow during emotional versus higher cognitive processes: Implications for interactions between emotion and cognition. *Cognition and Emotion*, 12, 353–385.
- Duncan, G. J., Dowsett, C. J., Claessens, A., Magnuson, K., Huston, A. C., Klebanov, P., et al. (2007). School readiness and later achievement. *Developmental Psychology*, 43, 1428–1446.
- Duncan, J., & Owen, A. M. (2000). Common regions of the human frontal lobe recruited by diverse cognitive demands. *Trends in Neurosciences*, 23, 475–483.

- Duncan, J., Seitz, R. J., Kolodny, J., Bor, D., Herzog, H., Ahmed, A., et al. (2000, July 21). A neural basis for general intelligence. *Science*, 289, 457–460.
- Eisenberg, N., Fabes, R. A., Nyman, M., Bernzweig, J., & Pinuelas, A. (1994). The relations of emotionality and regulation to children's anger-related reactions. *Child Development*, 65, 109–128.
- Eisenberg, N., Fabes, R. A., Shepard, S. A., Murphy, B. C., Guthrie, I. K., Jones, S., et al. (1997). Contemporaneous and longitudinal prediction of children's social functioning from regulation and emotionality. *Child Development*, 68, 642–664.
- Ellis, L. K., Rothbart, M. K., & Posner, M. I. (2004). Individual differences in executive attention predict self-regulation and adolescent psychosocial behaviors. In *Adolescent brain development: Vulnerabilities and opportunities* (pp. 337–340). New York: New York Academy of Sciences.
- Eriksen, B. A., & Eriksen, C. W. (1974). Effects of noise letters upon the identification of a target letter in a nonsearch task. *Perception and Psychophysics*, 16(1), 143–149.
- Espy, K. A., McDiarmid, M. M., Cwik, M. F., Stalets, M. M., Hamby, A., & Senn, T. E. (2004). The contribution of executive functions to emergent mathematic skills in preschool children. *Developmental Neuropsychology*, 26, 465–486.
- Eysenck, H. J. (1990). Biological dimensions of personality. In L. A. Pervin (Ed.), *Handbook of personality: Theory and research* (pp. 249–276). New York: Guilford Press.
- Fan, J., Flombaum, J. I., McCandliss, B. D., Thomas, K. M., & Posner, M. I. (2003). Cognitive and brain consequences of conflict. *NeuroImage*, 18, 42–57.
- Fan, J., McCandliss, B. D., Fossella, J., Flombaum, J. I., & Posner, M. I. (2005). The activation of attentional networks. *NeuroImage*, 26, 471–479.
- Fan, J., McCandliss, B. D., Sommer, T., Raz, A., & Posner, M. I. (2002). Testing the efficiency and independence of attentional networks. *Journal of Cognitive Neuroscience*, 14, 340–347.
- Fowles, D. C., & Kochanska, G. (2000). Temperament as a moderator of pathways to conscience in children: The contribution of electrodermal activity. *Psychophysiology*, 37, 788–795.
- Fuchs, L. S., Compton, D. L., Fuchs, D., Paulsen, K., Bryant, J. D., & Hamlett, C. L. (2005). The prevention, identification, and cognitive determinants of math difficulty. *Journal of Educational Psychology*, 97, 493–513.
- Gehring, W. J., Gross, B., Coles, M. G. H., Meyer, D. E., & Donchin, E. (1993). A neural system for error detection and compensation. *Psychological Science*, 4, 385–390.
- Gerardi-Caulton, G. (2000). Sensitivity to spatial conflict and the development of self-regulation in children 24–36 months of age. *Developmental Science*, 3, 397–404.
- Gonzalez, C., Fuentes, L. J., Carranza, J. A., & Estevez, A. F. (2001). Temperament and attention in the self-regulation of 7-year-old children. *Personality and Individual Differences*, 30, 931–946.
- James, W. (1890). *The principles of psychology*. New York: Holt.
- Jones, L. B., Rothbart, M. K., & Posner, M. I. (2003). Development of executive attention in preschool children. *Developmental Science*, 6, 498–504.
- Kiehl, K. A., Smith, A. M., Hare, R. D., Mendrek, A., Forster, B. B., Brink, J., et al. (2001). Limbic abnormalities in affective processing by criminal psychopaths as revealed by functional magnetic resonance imaging. *Biological Psychiatry*, 50, 677–684.
- Kochanska, G. (1993). Toward a synthesis of parental socialization and child temperament in early development of conscience. *Child Development*, 64, 325–347.
- Kochanska, G. (1997). Multiple pathways to conscience for children with different temperaments: From toddlerhood to age 5. *Developmental Psychology*, 33, 228–240.
- Kochanska, G., & Aksan, N. (2006). Children's conscience and self-regulation. *Journal of Personality*, 74, 1587–1617.
- Kochanska, G., Murray, K., & Coy, K. C. (1997). Inhibitory control as a contributor to conscience in childhood: From toddler to early school age. *Child Development*, 68, 263–277.
- Kochanska, G., Murray, K. T., & Harlan, E. T. (2000). Effortful control in early childhood: Continuity and change, antecedents, and implications for social development. *Developmental Psychology*, 36, 220–232.

- Kopp, B., Rist, F., & Mattler, U. (1996). N200 in the flanker task as a neurobehavioral tool for investigating executive control. *Psychophysiology*, 33, 282–294.
- Lengua, L. J. (2006). Growth in temperament and parenting as predictors of adjustment during children's transition to adolescence. *Developmental Psychology*, 42, 819–832.
- Luu, P., Tucker, D. M., Derryberry, D., Reed, M., & Poulsen, C. (2003). Electrophysiological responses to errors and feedback in the process of action regulation. *Psychological Science*, 14(1), 47–53.
- Mashburn, A. J., & Pianta, R. C. (2006). Social relationships and school readiness. *Early Education and Development*, 17, 151–176.
- McNab, F., Varrone, A., Farde, L., Jucaite, A., Bystritsky, P., Forsberg, H., et al. (2009, February 6). Changes in cortical dopamine D1 receptor binding associated with cognitive training. *Science*, 323, 800–802.
- Nelson, B., Martin, R., Hodge, S., Havill, V., & Kamphaus, R. (1999). Modeling the prediction of elementary school adjustment from preschool temperament. *Personality and Individual Differences*, 26, 687–700.
- Normandeau, S., & Guay, F. (1998). Preschool behavior and first-grade school achievement: The mediational role of cognitive self-control. *Journal of Educational Psychology*, 90, 111–121.
- Ochsner, K. N., & Gross, J. J. (2005). The cognitive control of emotion. *Trends in Cognitive Sciences*, 9(5), 242–249.
- Oldehinkel, A. J., Hartman, C. A., De Winter, A. F., Veenstra, R., & Ormel, J. (2004). Temperament profiles associated with internalizing and externalizing problems in preadolescence. *Development and Psychopathology*, 16, 421–440.
- Olesen, P. J., Westerberg, H., & Klingberg, T. (2004). Increased prefrontal and parietal activity after training of working memory. *Nature Neuroscience*, 7(1), 75–79.
- Olson, S. L., Sameroff, A. J., Kerr, D. C., Lopez, N. L., & Wellman, H. M. (2005). Developmental foundations of externalizing problems in young children: The role of effortful control. *Development and Psychopathology*, 17(1), 25–45.
- Passolunghi, M. C., Cornoldi, C., & De Liberto, S. (1999). Working memory and intrusions of irrelevant information in a group of specific poor problem solvers. *Memory and Cognition*, 27, 779–790.
- Posner, M. I., & DiGirolamo, G. J. (1998). *Executive attention: Conflict, target detection, and cognitive control*. Cambridge, MA: MIT Press.
- Posner, M. I., & Petersen, S. E. (1990). The attention system of human brain. *Annual Review of Neuroscience*, 13, 25–42.
- Posner, M. I., & Rothbart, M. K. (1998). Attention, self-regulation and consciousness. *Philosophical Transactions of the Royal Society of London, B*, 353, 1915–1927.
- Posner, M. I., & Rothbart, M. K. (2000). Developing mechanisms of self-regulation. *Development and Psychopathology*, 12, 427–441.
- Posner, M. I., & Rothbart, M. K. (2007). *Educating the human brain*. Washington, DC: American Psychological Association.
- Posner, M. I., Rothbart, M. K., & Sheese, B. E. (2007). Attention genes. *Developmental Science*, 10, 24–29.
- Posner, M. I., Rothbart, M. K., Sheese, B., & Tang, Y. (2007). The anterior cingulate gyrus and the mechanism of self-regulation. *Cognitive, Affective and Behavioral Neuroscience*, 7, 391–395.
- Posner, M. I., Rueda, M. R., & Kanske, P. (2007). Probing the mechanisms of attention. In J. T. Cacioppo, J. G. Tassinari, & G. G. Berntson (Eds.), *Handbook of Psychopathology* (3rd ed., pp. 410–432). Cambridge, UK: Cambridge University Press.
- Posner, M. I., & Snyder, C. R. R. (1975). Attention and cognitive control. In R. Solso (Ed.), *Information processing and cognition: The Loyola Symposium* (pp. 55–85). Hillsdale, NJ: Erlbaum.
- Raver, C., Blackburn, E. K., Bancroft, M., & Torp, N. (1999). Relations between effective emotional self-regulation, attentional control, and low-income preschoolers' social competence with peers. *Early Education & Development*, 10, 333–350.

- Rothbart, M. K. (2007). Temperament, development, and personality. *Current Directions in Psychological Science*, 16(4), 207–212.
- Rothbart, M. K. (in press). *Becoming who we are: Temperament and personality in development*. New York: Guilford Press.
- Rothbart, M. K., Ahadi, S. A., & Hershey, K. L. (1994). Temperament and social behavior in childhood. *Merrill-Palmer Quarterly*, 40, 21–39.
- Rothbart, M. K., & Bates, J. E. (2006). Temperament. In *Handbook of Child Psychology: Vol. 3, Social, emotional, and personality development* (6th ed.) (pp. 99–166). Hoboken, NJ: John Wiley & Sons, Inc.
- Rothbart, M. K., & Derryberry, D. (1981). Development of individual differences in temperament. In M. E. Lamb & A. L. Brown (Eds.), *Advances in developmental psychology* (Vol. 1, pp. 37–86). Hillsdale, NJ: Erlbaum.
- Rothbart, M. K., Derryberry, D., & Hershey, K. (2000). Stability of temperament in childhood: Laboratory infant assessment to parent report at seven years. In V. J. Molfese & D. L. Molfese (Eds.), *Temperament and personality development across the life span* (pp. 85–119). Hillsdale, NJ: Erlbaum.
- Rothbart, M. K., Ellis, L. K., & Posner, M. I. (2004). Temperament and self-regulation. In R. F. Baumeister & K. D. Vohs (Eds.), *Handbook of self-regulation: Research, theory, and applications* (pp. 357–370). New York: Guilford Press.
- Rothbart, M. K., Ellis, L. K., Rueda, M., & Posner, M. I. (2003). Developing mechanisms of temperamental effortful control. *Journal of Personality*, 71, 1113–1143.
- Rothbart, M. K., & Rueda, M. R. (2005). The development of effortful control. In U. Mayr, E. Awh, & S. W. Keele (Eds.), *Developing individuality in the human brain: A tribute to Michael I. Posner* (pp. 167–188). Washington, DC: American Psychological Association.
- Rueda, M. R., Checa, P., & Santonja, M. (2008, April). *Training executive attention: Lasting effects and transfer to affective self-regulation*. Paper presented at the annual meeting of the Cognitive Neuroscience Society, San Francisco.
- Rueda, M., Fan, J., McCandliss, B. D., Halparin, J. D., Gruber, D. B., Lercari, L. P., et al. (2004). Development of attentional networks in childhood. *Neuropsychologia*, 42, 1029–1040.
- Rueda, M. R., Posner, M. I., & Rothbart, M. K. (2004). Attentional control and self-regulation. In R. F. Baumeister & K. D. Vohs (Eds.), *Handbook of self-regulation: Research, theory, and applications* (pp. 283–300). New York: Guilford Press.
- Rueda, M., Posner, M. I., & Rothbart, M. K. (2005). The development of executive attention: Contributions to the emergence of self-regulation. *Developmental Neuropsychology*, 28, 573–594.
- Rueda, M. R., Posner, M. I., Rothbart, M. K., & Davis-Stober, C. P. (2004). Development of the time course for processing conflict: An event-related potentials study with 4-year-olds and adults. *BMC Neuroscience*, 5(39), 1–13.
- Rueda, M. R., Rothbart, M. K., McCandliss, B. D., Saccomanno, L., & Posner, M. I. (2005). Training, maturation, and genetic influences on the development of executive attention. *Proceedings of the National Academy of Sciences of the USA*, 102, 14931–14936.
- Ruff, H. A., & Rothbart, M. K. (1996). *Attention in early development: Themes and variations*. New York: Oxford University Press.
- Russell, R. L., & Ginsburg, H. P. (1984). Cognitive analysis of children's mathematical difficulties. *Cognition and Instruction*, 1, 217–244.
- Sanson, A., Hemphill, S. A., & Smart, D. (2004). Connections between temperament and social development: A review. *Social Development*, 13(1), 142–170.
- Santesso, D. L., & Segalowitz, S. J. (2009). The error-related negativity is related to risk taking and empathy in young men. *Psychophysiology*, 46(1), 143–152.
- Santesso, D. L., Segalowitz, S. J., & Schmidt, L. A. (2005). ERP correlates of error monitoring in 10-year-olds are related to socialization. *Biological Psychology*, 70(2), 79–87.

- Sheese, B. E., Voelker, P. M., Rothbart, M. K., & Posner, M. I. (2007). Parenting quality interacts with genetic variation in dopamine receptor D4 to influence temperament in early childhood. *Development and Psychopathology*, *19*, 1039–1046.
- Simonds, J., Kieras, J. E., Rueda, M., & Rothbart, M. K. (2007). Effortful control, executive attention, and emotional regulation in 7–10-year-old children. *Cognitive Development*, *22*, 474–488.
- Stevens, C., Fanning, J., Coch, D., Sanders, L., & Neville, H. (2008). Neural mechanisms of selective auditory attention are enhanced by computerized training: Electrophysiological evidence from language-impaired and typically developing children. *Brain Research*, *1205*, 55–69.
- Stevens, C., Lauinger, B., & Neville, H. (2009). Differences in the neural mechanisms of selective attention in children from different socioeconomic backgrounds: An event-related brain potential study. *Developmental Science*, *12*, 634–646.
- Stroop, J. R. (1935). Studies of interference in serial verbal reactions. *Journal of Experimental Psychology*, *18*, 643–662.
- Thorell, L. B., Lindqvist, S., Nutley, S. B., Bohlin, G., & Klingberg, T. (2009). Training and transfer effects of executive functions in preschool children. *Developmental Science*, *12*, 106–113.
- Valiente, C., Eisenberg, N., Smith, C. L., Reiser, M., Fabes, R. A., Losoya, S., et al. (2003). The relations of effortful control and reactive control to children's externalizing problems: A longitudinal assessment. *Journal of Personality*, *71*, 1171–1196.
- van Veen, V., & Carter, C. (2002). The timing of action-monitoring processes in the anterior cingulate cortex. *Journal of Cognitive Neuroscience*, *14*, 593–602.
- Venter, J. C., Adams, M. D., Myers, E. W., Li, P. W., Mural, R. J., Sutton, G. G., et al. (2001, February 16). The sequence of the human genome. *Science*, *291*, 1304–1351.