Title: The involvement of attentional mechanisms in children' self-regulation abilites

Authors: Carmen González[1], Luis J. Fuentes[2], & José A. Carranza[1]

(1) University of Murcia, Spain

(2) University of Almería, Spain

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Corresponding author: Carmen González. Depto. Psicología Evolutiva y Educación. Edificio Luis Vives. Universidad de Murcia. 30100 Espinardo, Murcia (Spain)

Tel.: +34 968 367692

Fax.: +34 968 364115

Abstract

The present work aims to address the study of the temperament dimension Self-Regulation in children, in connection to attention processes. The studies reviewed suggest that attentional mechanisms contribute to the development of emotional/behavioral self-regulation abilities. Individual differences in attentional control have also been found related to regulatory capacities. These findings support the hipothesis of a common biological basis. Although originally biological, self-regulation tendencies are shaped by experiential factors of the individual and by environmental influences. At this respect, the role of caregivers in guiding the developmental pattern of self-regulation is stressed.

THE INVOLVEMENT OF ATTENTIONAL MECHANISMS IN CHILDREN' SELF-REGULATION ABILITES

The concept of *self-regulation* refers to the ability of individuals to modify their behavior in responding to demands of specific situations (Block & Block, 1980; Kopp, 1982; Rothbart, 1989a). Self-regulation has been considered as a central dimension of temperament (Rothbart, 1989a), and recently some researchers have proposed that the attentional networks of the attention system play a crucial role in its development (Posner & Rothbart, 1998). In addition, as a sophisticated mechanism of adaptation to social environment, self-regulation is highly sensitive to environmental influences so that parents and caretakers play a central role in guiding the development of such abilities in infancy and childhood (Ruff & Rothbart, 1996). Therefore, self-regulation processes are conformed by the interaction of environmental factors with individual predispositions (Ruff, 1990), contributing in turn to psychological and social individual adjustment.

The present work aims to address the study of self-regulation as a concept influenced by biology as well as by social context. In the first section, the nature of self-regulation is addressed, stressing the relevance of Rothbart's theory to this issue. In the following sections, we address the involvement of attentional networks in the development of self-regulation throughout infancy and childhood. Other influences are also considered, such as cognitive-linguistic achievements, and social environment factors. We finish our discussion focusing on the implications of individual differences in self-regulation for social adjustment.

1. The concept of self-regulation

The study of self-regulation in infancy and childhood combines research from different disciplines, such as temperament, neuropsychology, motivation, and personality, and brings together areas from emotional, cognitive, behavioral, and even motor development (Grolnick, McMenamy, & Kurowski, 1999). Concepts such as behavioral inhibition, self-regulation, or ego control (e.g., Block & Block, 1980; Fox, 1989; Kopp, 1982), have been suggested from different perspectives, but all of them involve the ability to modify own behavior in response to cognitive, emotional, and social demands suggested by specific situations (Ruff & Rothbart, 1996).

From a temperamental point of view, Rothbart's theory has a special relevance to the present review because it has guided much research relating attentional networks and self-regulation abilities in children. Adopting a psychobiological perspective, Rothbart (Rothbart & Derryberry, 1981) defines temperament as constitutional individual differences in reactivity and self-regulation, which are influenced throughout time by heredity, maturation, and experience. Reactivity refers to responses of the emotional, activation, and arousal systems. Self-regulation includes processes such as approach, avoidance, and attention, which serve to modulate the reactivity of an individual. From this theory, babies are contemplated as highly reactive; however, as they grow older, early reactivity will progressively fall under control of self-regulation mechanisms (Rothbart, 1989c).

A major self-regulatory mechanism in Rothbart's theory, that is, Effortful Control, reflects individual differences in the *executive attentional network*, a set of neural circuits crucial for controlling attention to spatial and semantic information. Due to its wide access to representational content at cortex, and its ability to coordinate spatial and semantic attention, Effortful Control implies a flexible instrument of regulation. Effortful Control is identified with the concept of effort, volition, and operationally is reflected by individual

differences in the ability to voluntarily maintain attention to a given task, effortfully move attention from one task to another, and consciously initiate or inhibit an action. Given the sophisticated condition of this self-regulation mechanism, it emerges relatively late, in the second part of the first year of life, and continues maturing at least during the preschool period (Rothbart, 1989a, 1989b).

Thus, the development of self-regulation will rely on qualitative differences of the mechanisms involved in controlling individual´s behavior at each developmental moment. For instance, babies use frequently the strategy of shifting the orientation of attention to or far from objects or people (Rothbart, Posner, & Rosicky, 1994); however, as children grow older, the control becomes mainly verbal. Conceptualized in this way, the development of individual differences in self-regulation involves an organized system of psychological and neurophysiological processes which develop throughout time as a function of maturation and experience.

2. Involvement of attentional networks in the development of self-regulation

According to several theoretical approaches to the development of self-regulation (e.g., Block & Block, 1980; Kopp, 1982), children progressively improve their abilities, moving from rigid, rudimentary controls, to flexible mechanisms of adaptation which able them to exert a conscious, intentional, or voluntarily control on their own motivational functions. Thus, for instance, the rudimentary approach-withdrawal mechanism is frequently used by babies for regulating their emotional arousal. When confronted to new or uncertain stimuli, they could reduce or increase their activation level varying their approach to them. In contrast, more complex strategies will involve the different attentional networks (Rothbart, Posner, & Boylan, 1990). The changes in self-regulatory abilities

undergone with development, are considered facilitated by biological maturation, as well as by experience. At this respect, parents play a major role, whose sensitive care will give their children opportunities to learn effective forms of control.

Investigations with babies have revealed the early presence of a variety of attentional forms which have been well documented in adults. However, the fact that such functions show different developmental patterns suggests that they are dissociable in infancy, as they are in adulthood, and also it gives support to the hypothesis that they are fed by different neural substrates (Colombo, 2001). Fathoming in the implication of the attentional networks in self-regulation skills, Posner and Rothbart (1998) propose that the maturation of the attentional mechanisms underlie the development of self-regulation in infancy. Let us summarize the development of attentional functions in infancy and how they can contribute to qualitative changes in children's behavior.

2.1. Alert Network

The alert network matures very early and is predominant during the first months of life. In adults, this network has been studied in sustain attention, or vigilance tasks, and seems to reflect the control of low level attentional functions by higher level structures (e.g., the influence of cortical areas on subcortical areas). However, in babies, during the first three months of life, the alert network would be more easily activated by exogenous events (Wolff, 1965) or by mechanisms of low level arousal (Karmel et al., 1991), rather than by endogenous or voluntary sources. For that reason, such network in infancy cannot be linked to vigilance or sustain attention. In contrast, its functioning will be initiated in a subcortical structure, the stem brain, with four ascendant paths to neocortical areas associated with attentional functions (Colombo, 2001). The best known pathway is

involved in the maintenance and adjustement of the different phases of the general alert, through norepinephrine projections from the locus coeruleus to the cortex (Posner & Raichle, 1994; Posner & Rothbart, 1992). This mechanism may facilitate adaptive behavior, focusing attention on motivationally relevant stimuli avoiding distraction. This attentional network facilitates automatic orienting responses, generating a link between the child and his/her environment. In neonates, the alert state period in a 24 hours cycle is rather short compared to sleep (75% sleep; less than 20% awake) but drastic changes are produced in few weeks, so that 15-weeks-olds' alert periods adjust properly to darkness-light cycle, and the child will be able to keep alert for longer (Berg, 1979).

Attention mechanisms have been characterized as "reactive" (Ruff & Rothbart, 1996) at this period, because visual orientation to exogenous stimulation is highly influenced by objects' characteristics. An instance of such influence comes from the obligatory looking in which the young baby is frequently "captured" by stimulus characteristics (e.g., white/black contrast as in a chess board). The obligatory looking phenomenon is produced because the superior colliculus is still inmature, and can otherwise explain children's difficulties to regulate their own emotional arousal (Johnson, Posner, & Rothbart, 1991). That is, if a baby starts crying, s/he will experiment difficulties to sooth because of her/his inability to "disengage" and move attention away from the source of distress. Although neonates are provided with some reflects (e.g., close the eyes, turn the head), which help them to withdraw from aversive or overwhelming stimuli in the first months of life, the level of arousal may exceed their self-regulation abilities, becoming necessary external help (Kopp, 1989). For that reason, the role of caregivers in regulating babies' arousal gets a higher relevance at this period (Ruff & Rothbart, 1996). In most cases, parents are sensitive to indications provided by their babies, increasing or decreasing

the intensity of stimulation based on their children's hedonic state. However, sometimes adults may over-stimulate their children, leading them to cry (Brazelton et al., 1974).

2.2. Orientation Network

A second set of neural circuits involve orienting attention from one location to another, as well as adjusting the attention scale or amplitude. It becomes apparent in 4 month-old babies. This orienting network is distributed through the posterior parietal lobe, the mid-brain superior colliculus, and the pulvinar nucleus of the thalamus. Its functioning can be better understood in terms of operations that allow attention to "disengage" from one location, "move" to another location, and "engage" or power that location, respectively. When it is involved in a given location, its amplitude can narrow to provide details of local characteristics or, alternately, it can provide a wider covering of global information (Posner & Raichle, 1994; Posner & Rothbart, 1992; Rothbart, Posner & Rosicky, 1994). Due to the maturation of the superior colliculus-posterior parietal cortex connections by 4 months of age, children improve their ability to disengage attention from stimuli to which have been habituated (Johnson, Posner, & Rothbart, 1991).

While the orienting network provides objects' spatial coordinates, visual properties such as shape or color, are perceived in a pathway that extends from the occipital cortex to higher order visual areas of the posterior inferior temporal cortex and the inferior temporal cortex. Although this network is probably active since birth, substantial changes appear from 2 to 5-6 months of age, so that babies will have a new cognitive source available, that is, focused attention. Thus, the orienting network will be used to shift attention from one stressing stimulus, allowing concentration of cognitive activity on a different stimulus, facilitating the regulation of negative emotion, and consequently decreasing the amount of

crying and fussing. This strategy of self-distraction by actively engaging in objects to reduce the level of arousal in emotional activation situations, has been documented in 6-month-old children (e.g. Harman, Rothbart & Posner, 1997; Mangelsdorf, Shapiro & Marzolf, 1995).

2.3. Executive Network

Later in the first year of life, it becomes apparent the presence of an endogenous visual attention network that involves some portions of the frontal cortex and the anterior cingulated cortex. This executive attentional network modulates the orienting attentional network and controls attention to language (Fuentes, Carmona, Agis, & Catena, 1994; Fuentes,Vivas, & Humphreys, 1999; Posner & Riachle, 1994; Rothbart, Derryberry, & Posner, 1994). This network is also involved in two major functions: (1) the voluntary direction of attention in response to tasks demands, and (2) the ability to inhibit or maintain the attention toward a stimulus, event or undergoing task.

Although there are reasons to suggest the presence of some rudimentary forms of endogenous visual attention in neonates, there is a strong evidence supporting that such functions emerge and dramatically change during the last part of the first year of life and later. The endogenous attention becomes apparent in infancy by multiple ways. For instance, in the habituation paradigm the rapid alternative fixation on two stimuli presented at the same time, seems to reflect an active process of comparing both stimuli (Colombo et. al, 1990). Another index of endogenous attention is the decrease in the tendency to distraction and, as a consequence, the involvement in sustain attention for longer periods of time (Ruff, Capozzoli, & Saltarelli, 1996).

Furthermore, endogenous attention is reflected in children's ability to inhibit prepotent responses under certain circumstances. For instance, when presented with a transparent box containing objects inside, children under 9 months of age show a tendency to try to grasp them directly, crashing into the transparent barrier. Diamond (1991) characterizes this direct reaching behavior as a prepotent response, because it had been previously rewarded and has become usual, and therefore difficult to resist. In contrast, children above 9 months of age are able to round the box, find its opening, and successfully reach the object.

This ability to inhibit responses has been recently proposed as an explanation of the poor performance exhibited by children under 8 months of age in the classic piagetian A-not-B task (Diamond, 1991). Such task consists of alternately hiding a small object under one of two cloths on a table, set up equidistant from the child. Once the object has been hidden under one of the cloths, and reached by the child, then, while the child is looking, the object is hidden again, but this time under the alternative cloth. The child is permitted to grasp the object after several seconds of delay. The classic theory, based on working memory limitations, suggested that two different forms of processed information become in conflict: on the one hand, the location where the object was previously found and therefore rewarded, and, on the other, the new location where the object was finally hidden. According to Diamond (1991), to resolve the problem it is not only necessary to organize both events in a temporal sequence, but also to inhibit a prepotent response (to go to the previously rewarded location), which would be incompatible with the current goal (to find the object in the place where it was finally put).

This inhibition ability linked to the executive network, seems to play a role in emotional and behavioral regulation. Rothbart, Posner, and Boylan (1990) suggested that

the executive attentional network interacts with subcortical structures of the limbic system, especially the amigdala and the thalamus, which would work together in processing emotional information. Specifically, the anterior cingulate gyrus would control the executive attention functioning, while receiving input coming from the networks associated with distress. In the same line, Vogt, Finch, and Olson (1992) proposed that the anterior cingulate cortex, due to its connections to the motor cortex, can be a candidate place for the interaction between cognitive and motivational processes, especially those related to motor output.

In summary, the improvement of self-regulation abilities has been associated with the maturation of attentional networks. However, self-regulation processes are also influenced by other aspects of individual development. Thus, other brain maturational changes are relevant like the drastic increase in coherence between the left frontal hemisphere and parietal regions (Tatcher, 1994). Moreover, the myelinization of the frontal cortex is produced rapidly until 3 years of age and continues until early adolescence (Pfefferbaum et al., 1994). All these changes are redundant to produce a communication more elaborated and efficient between anterior and posterior regions of the brain, which in turn permits the executive network to control the orientation network, leading to true demonstrations of flexible control of behavior in response to changing situations.

Other qualitative changes in children's cognitive capacities have been also connected to self-regulation. At this respect, Piaget (1961) highlighted the emergence of the symbolic function, which involves a major change in managing the physical and social world. Mental representations will able the child to anticipate future states of self and

world, so that s/he could evaluate the consequences of potential actions, necessary for a strategic voluntary control (LeDoux, 1989).

Thus, the development of self-regulation skills in infancy and childhood have been linked to the maturation of the brain as well as to cognitive-linguistic achievements. However, the role of parents is also important. It is in the third year of life when parents stress the necessity of a self-generated control. Children are expected to follow some demands, even when parents are not present (Kopp, 1982). Nevertheless, in some cases, when children are prohibited to touch a desired object (e.g., the television remote control), without parent's surveillance, they will not obey always such restriction. These limitations showed at a behavioral level, are also apparent at an emotional level, and the lack of control of negative emotions in frustration situations will be expressed by temper tantrums. Kopp (1989) characterizes this period as progression-regression. Progression is apparent by the increase in autonomy; regressions are when attempts of autonomy are frustrated by caregiver prohibitions or due to discrepancy between the child's goals and his/her capacity of a self-initiated action.

Throughout preschool years, a progressive improvement of self-regulation capacities undergoes. Vaughn, Kopp and Krakow (1984) found an increase in self-control abilities as a function of age in 18, 24, and 30 month-old children, using tasks in which children had to wait to eat candies or touch attractive toys. More recently, Gerstadt, Hong, and Diamon (1994) tested children of different ages in a complex conflict task in which they had to follow verbal orders, given by two voices at the same time. Children were asked to follow the instructions given by one of the sound sources, ignoring the other. A great improvement from 42 to 46 months of age was found. In connection with the progressive mastering of such skills, Gerardi (1997) found a drastic improvement in performing a

Stroop-like task from 24 to 36 months of age. Taken together, these findings suggest that behavioral/emotional and attentional control develop in a parallel way throughout preschool years.

In explaining this progressive control by the child, it is worth to mention the regulatory function of language in the preschool period. At this respect, Vygotsky's and Luria's frameworks are considered fundamental for understanding the transition from an external to an internal control. They considered such transition is facilitated by the emergence of a private speech, that is, the speech not directed to a speaker, which includes words games, affect expressions, and comments and questions raised while performing a task. This speech, which will become silent late in the preschool period, has been found associated with focused attention and behavioral inhibition in performing a given task (Bivens & Berk, 1990).

Later in childhood, the progressive emotional control will be more internally governed. At this respect, Eisenberg (1998) stressed the gradual change in emotion and behavior regulation from external sources, such as the socialization agents, to self-initiated internal sources, based on the child himself. As children's cognitive capacities improve, they no longer need their caregivers to help them understand and control emotions. With respect to the expression of emotions, along with being instructed about how they "should" feel in different situations (Hochschild, 1979), children also learn that demonstrations of emotions should be suppressed or overdone in some cases. Saarni (1979) studied the behavior guided by social rules in children from 6 to 10 years of age, and found that older children knew a higher number of and more complex rules in comparison to younger ones. The cognitive knowledge of possible dissociations between feeling and action, and the

intentional dissimulation in connection to it (Selman, 1980) are also important changes that probably take place at this period in the socialization of emotions.

Thus, and as a conclusion, the works reviewed here show that the development of self-regulation depends on multiple factors, including social context influences, individual cognitive-linguistic capacities, and maturation of brain. The fact that the maturation of attentional networks is involved in the improvement of self-regulation abilities, seems to give support to the hypothesis that both share a common biological basis.

3. Individual differences in attention and self-regulation

More empirical support for the common biological basis hypothesis comes from the evidence that individual differences in attention are related to self-regulatory capacities of the individuals at different developmental periods. At this respect, concurrent relations between attention and negative emotionality have been repeatedly found in children.

In infancy, Fagen, Ohr, Singer and Fleckenstein (1987) found that the amount of crying in 3 and 4 month-olds, and their ability to complete an operant conditioning task, were negatively correlated to the temperament dimension Duration of Orienting, as informed by their mothers through the Infant Behavior Questionnaire. Similarly, Wachs & Smitherman (1985) found a positive relationship between fussing and low adaptability, and the fail in completing a habituation task in children from 2 to 6 months old.

Focusing on the preschool period, children from 27 to 36 months who successfully performed a spatial conflict task were described by their parents as good in shifting and focusing attention, less impulsive and with a lesser tendency to show anger reactions (Gerardi, 1997). By using laboratory tasks, González et al. (2001) found that a high anger and a low inhibitory control was associated with a higher Simon interference in 4-year-olds.

Already in middle childhood, González et al. (2001) found that negative emotionality and poor behavioral self-regulation were associated with a worse attentional control in 7-8 year-olds. In such work, two versions of the Stroop task were administered; in one each stimulus was presented alone in the screen; in the other version the stimulus appeared flanked by distractors. It permitted to dissociate two interference effects: the Stroop and the flanker effects, relying mainly on the executive and the orientation networks, respectively. Temperament was measured through the questionnaire Children's Behavior Questionnaire. Interestingly, different temperament dimensions were associated to each attentional network: while a higher Stroop interference was associated with a high level of activity and impulsivity, and with a low inhibitory control, flanker interference related to a high anger, discomfort, and sadness. In this study, the executive network was associated mainly with behavioral regulation, while the orientation network was related to emotional regulation.

In older children (from 11 to 14 years old), individuals who informed of a high ability to shift and focus attention, also informed of a lesser susceptibility to negative emotions such as fear, frustration, and irritability (Derryberry & Rothbart, 1988).

Taken together, all these results show concurrent associations between attentional control and emotional/behavioral self-regulation. These findings have been also supported by predictive studies. Thus, for instance, Riese (1987) found that a higher irritability in the neonatal period was associated with lesser levels of attention at 2 years old. Lawson and Ruff (1988) found that the intensity of negative emotionality at 12 months of age, measured through both laboratory and caregiver's report, correlated with shorter duration of focused attention at 3.5 years. Later in childhood, Shoda, Mischel and Peake (1990) found that

preschoolers who showed a higher capacity to delay the reward in a conflict situation were more attentive and coped better with stress in adolescence.

4. Self-regulation: from biology to social context

Results from the studies reviewed here lead us to contemplate attention as a process serving to a more general self-regulation ability with a high biological component and involving a set of cognitive, motivational, and experimental aspects of the individual, which are all intercorrelated.

From this conceptualization however, while individual differences in self-regulation are originally biological, environmental influences are necessary as agents of change of such predispositions (Derryberry & Rothbart, 1997). At this respect, caretakers play a major role in the development of children's self-regulation. In fact, there is evidence that parents improve their children's shift and focus of attentional patterns (e.g., Belsky, Goode, & Most, 1980), reduce the expression of negative emotionality (e.g., Belsky, Fish, & Isabella, 1991), or facilitates the use of active self-regulation strategies (Grolnick, McMenamy, & Kurowski, 1999).

In turn, such self-regulatory strategies will play a central role in children's socialization process and therefore on their social functioning. Thus, for instance, Kochanska and colleagues (1995, 1996) showed that a high inhibitory control and fear in the preschool period, facilitate the internalization of social rules, as it was obtained measuring how obedient the children appeared to their mothers' demands and prohibitions. Such early self-regulation abilities may have a pervasive long term influence on social functioning, as Caspi (2000) showed in an impressive longitudinal study from preschool period to adulthood. It was found that children diagnosed as Inhibited -that is, socially

reticent, fearful, easily upset by strangers in performing a battery of cognitive-motor developmental tasks- at 3 years, showed a poor social support (as measured by a self-report about available friends for mentorship, companionship, material and emotional support) when they were 21 years old. On the other hand, the 3-year-old Undercontrolled children (characterized as impulsive, restless, negativistic, distractible, emotional labile) lacked as well of companionship and emotional support but showed in addition, unsatisfactory intimate relationships. Contrarily, the third group, the Well-adjusted, showed a satisfactory social and marital support.

Finally, and summarizing, the study of self-regulation in infancy and childhood is necessarily multidisciplinary, due to the variety of phenomena it involves. In explaining the development of self-regulation, the maturation of attentional networks have been given an important role in contributing to the improvement of behavioral and emotional control exhibited by children as they grow older. Furthermore, individual differences in attentional control have repeatedly been associated with behavioral and emotional control at different ages. These findings are anchoring our understanding of how motivational and cognitive processes interact to configure individual personality. Moreover, environmental influences, and especially caregivers, may guide the developmental pattern of self-regulation and, in the end, individual social adjustment.

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