TESIS DOCTORAL

Metacognition, attention and self-regulation: Development and enhancement with training

(Metacognition, atención y auto-regulación)

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METACOGNITION, ATTENTION AND SELF-REGULATION

DEVELOPMENT AND ENHANCEMENT WITH TRAINING

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Chapter 1.

Theoretical and empirical background.

1.1 Introduction: Attention as a cognitive control mechanism

One of the key features that enable human's coherent behaviour and cognition is our ability to organize, regulate and adapt to a changing environment in order to accomplish goals. Since ancient times, different philosophers and influential figures throughout human history attributed to the ability of self-regulation an essential role for the individual wellbeing. However, it was not until the emergence of scientific psychology at then end of the 19th century that a comprehensive and operationalized framework was developed with the purpose of studying, measuring and understanding the mechanisms underlying such abilities. Regulation skills can be integrated within the framework of cognitive control mechanisms, which can be defined as a set of cognitive processes that interact with each other in order to detect, integrate and process information to produce the most suitable behavioural outcome according to particular circumstances.

One of the first authors to describe such cognitive control mechanisms was William James, one of the forefathers of modern Psychology. James linked the ideas of volition and control to attention, a process that he described as "the taking possession by the mind in clear and vivid form, of one out of what seem several simultaneously possible objects or trains of thought...It implies withdrawal from some things in order to deal effectively with others, and is a condition which has a real opposite in the confused, dazed, scatter-brained state." (p. 403) (James, 1890). Despite being quite subjective, this early definition undoubtedly shed some light on the various cognitive mechanisms underlying attention and provided a conceptual framework that was used years later in further efforts to understand this function and its neural basis.

Attention processes have been the subjects of a thorough investigation in the past decades, especially since the emergence of Cognitive Psychology in the 1950s (Miller, 2003). Thanks to the vast amount of data that has been gathered within this research tradition, it has been possible to uncover different cognitive processes that act as part of the attention system, with the subsequent emergence of models that try to provide a comprehensive framework of attention. With the help of modern cognitive neuroscience techniques it has been possible to test the different models and outline the brain structures and neural networks underlying attention processes.

One of the first models to portrait attention as a central cognitive control mechanism was the Supervisory Attentional System by Norman and Shallice (1986). This model was introduced as a way to explain how automatic and control processes, two very different but interrelated processes, act and interact with each other in order to produce coherent goal-driven behaviour (Posner & Snyder, 2004). Generally, the model instates that with sufficient practice individuals develop a set of well-learned routines that don't require much of attention to be executed. These actions can be initiated without deliberate attention (e.g. eating while talking), carried out without awareness (e.g. walking), even when attention is drawn automatically to something (e.g. orienting to a novel stimuli), and can be performed without interfering with other, more important tasks (e.g. brushing our teeth while reading an email). Norman and Shallice (1986) proposed that these automatic well-learned actions are controlled by a set of mechanisms that act activating and inhibiting schemas called the *contention scheduling mechanism*. When a simple, well-learned action sequence is performed, a set of schemas that represent this sequence is activated by a perceptual event. This set of schemas constitutes each one of the processes that has to be performed in order to complete the action. For example, the act of drinking from a cup leads to the activation of schemas that control the extension of the arm, the opening of the hand and graving of the cup, the contraction of the hand and the careful placing of the cup on the lips.

However, not all actions that we perform in our lives are automatic. During the day we face situations that require a) planning and decision making, b) novel sequences of actions, c) overcoming of strong habitual responses, d) different kinds of conflict that need to be resolved, and/or e) situations that pose some degree of threat or danger that are better faced with careful attention (Norman & Shallice, 1986). In most cases, both automatic and controlled processes are involved. For example, one could imagine a situation in which somebody buys a new racing motorbike after having owned a scooter for a long time. Even though the general schemas of balance and driving (e.g. put on a helmet, look at the side mirrors, use the side lights to mark your way) are already learned, one needs to commit more resources to learn the new schemas required for properly driving of the new motorbike (e.g. how to change gear, be aware of the r.p.m. indicator). Norman and Shallice argue that in these cases the implementation of the Supervisory Attention System (SAS) enables the voluntary activation and inhibition of schemas. In their model, they explain how the SAS acts as a control-selection mechanism that helps the individual to select the best response when facing with novel situations that do not fit with the automatic response schemas that are available for that particular individual.

One of the most influential models of Attention, the neurocognitive model of Michael Posner (Petersen & Posner, 2012; Posner & Boies, 1971; Posner & Petersen, 1990), does not considers attention as a unitary control system but instead as a multimodal system that is involved in reaching and maintaining an adequate level of alertness, selecting and prioritizing the processing of relevant information, and monitoring and controlling the processing of information in a top-down dynamic. In the following section we will discuss the neurocognitive model of Michael Posner.

1.2 The neurocognitive model of Michael Posner

At the moment, one of the most well-established models concerning attention is the neurocognitive model of Michael Posner (Petersen & Posner, 2012; Posner & Petersen, 1990). Posner and Petersen (1990) suggested that, contrary to other cognitive systems, the attention system is not involved in processing information but on modulating and controlling the actions of systems that do so. In this sense, attention is conceived as a domain-general system involved in a wide range of actions. Additionally, attention is linked to a set of neuroanatomical networks. It is neither the property of a single centre nor a general function of the brain. Thus, Posner and Petersen described attention as a modular system related to three different brain networks involved in alerting, orienting, and executive control (Petersen & Posner, 2012; Posner & Petersen, 1990; Posner et al., 2007) (figure 1.1).

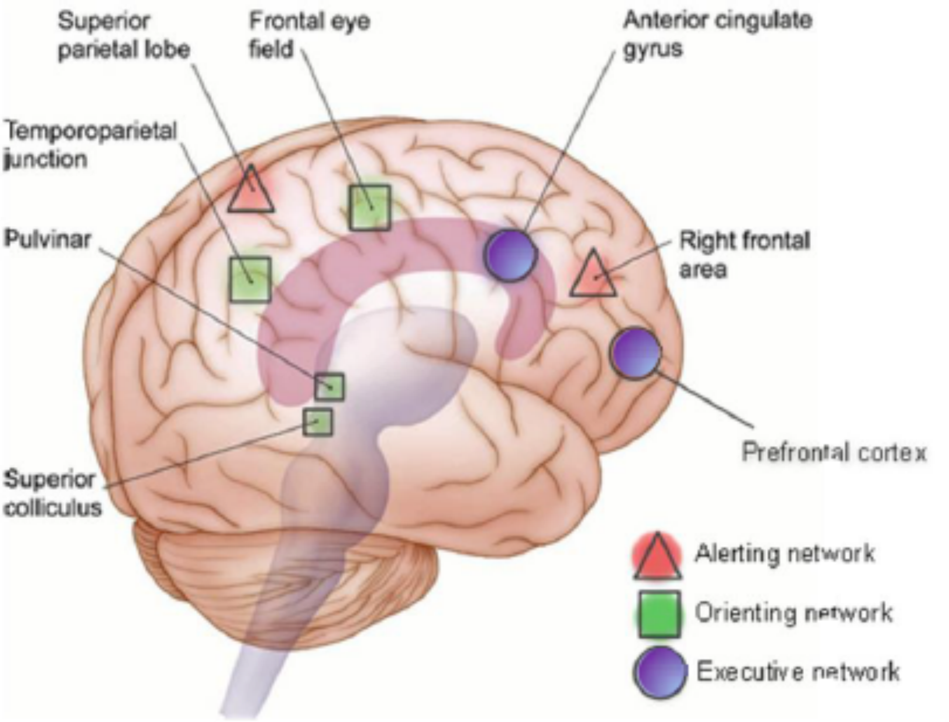

Figure 1.1. Main brain structures associated with each attention network. From Posner, Rueda & Kasnke (2007).

The alerting network is involved in coordinating changes in arousal state by either maintaining a vigilant state (tonic alertness) and/or preparing the organism to respond following a sudden and often unexpected change of stimulation (phasic alertness) (Petersen & Posner, 2012; Posner et. al., 2007). Tonic alertness refers to changes on the state of vigilance that occurs throughout a period of time. Some of the methods that have been used to assess tonic alertness include studying vigilance changes over the course of the day (circadian rhythms) or along extended periods of task performance. On the other hand, phasic alertness relates to the changes in the state of activation that are produced by the presentation of an external stimulus. The method to study phasic alertness often involves the presentation of a warning signal prior to a target stimulus, which increases the level of activation of the organism. In these studies, a trade-off between RT and accuracy is usually found. While the warning signal produces faster responses, the RT reduction is frequently accompanied by poorer response accuracy (Callejas, Lupiáñez, & Tudela, 2004; Posner et. al., 2007). The alerting network is supported by a set of brain networks that include areas in the right frontal and parietal cortex, and also subcortical regions such as the locus coeruleous (Aston-Jones & Cohen, 2005; Aston-Jones, Rajkowski, & Cohen, 1999; Petersen & Posner, 2012; Posner et al., 2007b). Recent works link the activity of the alerting system with the neurotransmitter norepinephrine, demonstrating robust wake-promoting actions of the locus coeruleous-noradrenergic system (Aston-Jones & Cohen, 2005; Berridge & Waterhouse, 2003; Berridge, 2008).

The orienting network is related to the ability to prioritize sensory input by controlling perceptual processing, orienting the receptors and selecting relevant information for further processing. The orienting of attention can be generated endogenously (voluntary or top-down attention) or influenced by exogenous cues (stimulus-driven or bottom-up attention). Although there is an anatomically defined orienting network, differences have been found in the brain network dynamic related to the way attention is oriented (top-down vs. bottom-up). Corbetta and Schulman (2002) have suggested that two distinct networks interact in order to orient attention to external stimulation. On the one hand, a dorsal fronto-parietal network, that includes regions of the dorsal parietal cortex (intraparietal sulcus and superior parietal lobule) and dorsal frontal cortex (precentral sulcus, near the frontal eye fields). This network is involved maintaining endogenous attention based on current goals and expectations and sends top-down signals that bias the processing of relevant stimulus features and locations in sensory cortex (Corbetta, Patel, & Shulman, 2008; Corbetta & Shulman, 2002). On the other hand, a ventral fronto-parietal network is activated when behaviourally relevant stimuli are detected. The regions that are related to the ventral network are the temporo-parietal junction (TPJ), the supramarginal gyrus (SMG), parts of the middle frontal gyrus (MFG), inferior frontal gyrus (IFG), frontal operculum and anterior insula (Corbetta et al., 2008; Corbetta & Shulman, 2002; He et al., 2007). When engaged in a task, the dorsal network its activated so we can apply a rapid strategic control over attention. However, when a salient object suddenly appears, output from the ventral network works as a "circuit-breaker" that interrupts the on-going selection processing of the dorsal network, which allows the reorienting of attention to the novel stimuli. There is evidence that the orienting of attention is mostly modulated by acetylcholine, and that the cholinergic system of the basal forebrain plays a critical role in the orienting of attention (Petersen & Posner, 2012).

The executive attention network is related to the control of cognition and behaviour. This network exerts its top-down control through processes related to target detection, conflict resolution, error detection and inhibitory control (Botvinick, Braver, Barch, Carter, & Cohen, 2001; Botvinick, Cohen, & Carter, 2004; Petersen & Posner, 2012; Posner & Petersen, 1990; Rueda, Rothbart, McCandliss, Saccomanno, & Posner, 2005; Simonds, Kieras, Rueda, & Rothbart, 2007). Through this set of processes, executive attention allows individuals to adjust their behaviour and cognition in order to fit with the various conditions and circumstances that are faced moment to moment. It has been suggested that this network relies on the dopaminergic system, that projects from ventral tegmental areas, and is supported by a neural network that includes the anterior cingulate cortex, lateral and ventral prefrontal regions, as well as the basal ganglia (Dosenbach, Fair, Cohen, Schlaggar, & Petersen, 2008; Posner et al., 2007b; Yeung, Botvinick, & Cohen, 2004). The executive network has been closely related to self-regulation of emotion and behaviour (Kanske & Kotz, 2011; Rothbart & Rueda, 2005; Simonds et al., 2007), school achievement (Rueda, Checa, & Rothbart, 2010) and deficits in its efficiency have been associated with different neuropsychological conditions like ADHD (Groom et al., 2010; Wiersema, van der Meere, & Roeyers, 2005), anxiety (Pacheco-Unguetti, Acosta, Callejas, & Lupiáñez, 2010) and schizophrenia (Luck et al., 2009).

Due to the strong relation between executive attention and socio-emotional well being, the work presented on this thesis focuses on how to foster the efficiency of the control mechanisms, with a special focus on the mechanisms related to the executive attention networks. Therefore, in the following section, a detailed account of the mechanisms and neural bases of the executive attention network is presented.

1.3 Executive attention network

As explained above, the executive attention network is described as a cognitive control system that support goal-driven behaviour by implementing monitoring, conflict resolution and inhibitory control processes (Rueda, Posner, & Rothbart, 2005). Conflict monitoring and resolution has been studied extensively in cognitive psychology using tasks where the experimental conditions differ in the amount of conflict between task relevant and task irrelevant dimensions of the stimulation. In the *congruent* condition different dimensions of the stimuli elicit the same response tendency, whereas when these dimensions are *incongruent* they induce a conflict between response tendencies. In the former condition a response is produced faster and more accurately due to the lack of conflict, while in the later the participant is prone to execute a dominant response that has to be suppressed yielding to slower and less accurate responses. The most common paradigms used for this are the so-called Stroop task and the flanker task (Davies, Segalowitz, Dywan, & Pailing, 2001; Falkenstein, Hoormann, Christ, & Hohnsbein, 2000; Green & Malhi, 2006; Kanske, 2008; Posner, et. al, 2007; Rueda, et. al., 2005; Ullsperger & von Cramon, 2004).

One of the classical tasks used for assess conflict resolution is the Stroop color-naming task (Stroop, 1935). In this task, participants are required to name the colour in which words are displayed and ignore the meaning of the word. In the congruent condition both dimensions of the word coincide (e.g. “RED”), whereas in the incongruent condition the dimensions are different (e.g. “RED”) thus eliciting conflict between the dominant tendency (i.e. reading the word) and the non-dominant but correct response (i.e. naming the color). In order to resolve this conflict, participants need to suppress the habitual tendency of reading the word to produce the appropriate answer. The result is a consistent slower response time (RT´s) on incongruent conditions compared to congruent conditions, a measure known as the congruency effect.

The flanker task (Eriksen & Eriksen, 1974) is another classical task used to asses conflict resolution. In this task, participants are presented with a stimuli composed by a string of 5 letters, and they are asked to identify the letter at the centre of the row. These stimuli can be congruent; when the 4 flanker letters are the same (e.g. HHHHH, SSSSS), or incongruent, when the center stimulus and the flanking stimuli are different (e.g. HHSHH, SSHSS). A modified version of the flanker task uses arrows pointing at either direction (right or left). In this case, the task is to indicate the direction in which the central arrow its pointing. A conflict is elicited when the flanker arrows point to a different location than the target (e. g. congruent: →→→→→; incongruent: →→←→→). In order to resolve the conflict, participants need to be able to focus attention on the target stimulus and to suppress the influence of the flanker stimuli. Similar to the stroop task, the congruency effect its characterized by slower RT's and higher percentage of errors in the incongruent compared with the congruent condition.

Inhibitory control can be assessed by tasks where a predominant response its developed by asking the participant to responds as quick as possible to the target trials (Go) and to withhold the response to either another stimuli or to a stop-signal. One of the most used paradigms to study inhibitory control, it's the Go/NoGo task. In this task, participants have to respond (e.g. press a key) as fast as they can when a Go stimulus is presented and withhold the response to No-Go stimuli. Presenting a higher proportion of Go trials than No-Go trials creates a tendency to respond, which has to be inhibited when No-Go stimuli are presented. To assess inhibitory control, this task provides indexes based on the number of false alarms (i.e. response to the No-Go trials), such as the sensitivity index or d', as well as other indexes related to self-regulation, such as the post-error slowing.

Although the three attention networks are related to processes that may seem to act independently from each other and that relies in relatevely different brain structures (Aston-Jones & Cohen, 2005; Botvinick et al., 2004; Corbetta et al., 2008; Petersen & Posner, 2012), several studies have gather data that demonstrate the interactive functional dynamic between networks.

1.4 The Attention Network Task (ANT)

Early in the 2000s, Fan et al. (2002) developed an experimental paradigm known as the Attention Network Task (ANT) with the purpose of measuring the efficiency of each attention function. This task combines a set of paradigms traditionally used to study alerting (warning signals), orienting (orienting cues) and executive control (flanker task), using RT and response accuracy to calculate scores for each of the attention networks as index of network efficiency. In the original version of this task (Fig. 1.2) the target appeared either above or below a fixation cross. Each target was preceded by one of four cue conditions: no cue, central cue, double cue or spatial cue. The alerting score is calculated by subtracting responses to trials that present a warning cue (double cue) from trials without warning cue, providing a measure of the benefit in performance of having been prepared from a warning cue. The orienting score is computed by subtracting trials with spatial cue from trials with central cue and provides information about the benefit obtained from the information of the location of the upcoming target. The executive attention network score offers information about the interference effect of the flankers and is obtained by subtracting responses to congruent flankers from incongruent flankers trials. Results of this study showed that even if the three attentions can be reliably measured as independent processes, an interaction between the alerting condition and the flanker congruency was detected, evidenced by an increase in the flanker congruency effect after a warning cue with no spatial information was presented

(Fan, McCandliss, Sommer, Raz, & Posner, 2002). This interaction was interpreted as an artifact effect due to specific features of the task.

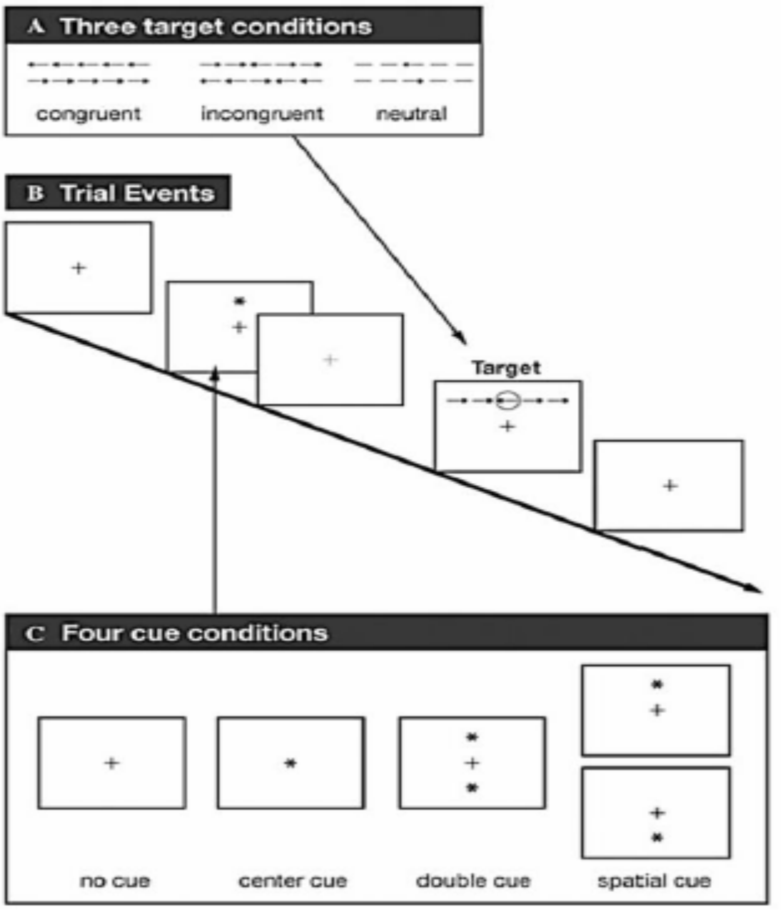

Figure 1.2. Schematic representation of the original version of the ANT. From Posner (2005).

In order to test this assumption Callejas, Lupiañez and Tudela (2004) conducted a study in which they modified the original ANT by including an auditory alerting cue different from the visual orienting cues, allowing the measure of the interaction between alerting and orienting. They also included an invalid orienting cue (uncued trials), which allows the assessment of the process of disengagement and reorienting of attention. Results of this study evidence the presence of interactions between the three attention networks. The authors described an interaction between the alerting and executive attention network, which consisted on larger congruency effects (larger RT difference between incongruent and congruent trials) in the presence of an alerting warning cue. Authors suggested that this interaction indicates an inhibitory influence of alerting on the executive attention network, which produce fast responses to infrequent sensory stimuli in order to prevent the system to focus on furthering processing of the stimuli (Callejas et al., 2004). Results also show the presence of an interaction between the orienting and the executive attention network, which consisted in larger congruency effects in cued trials compared to uncued trials. This effect was interpreted as faster RT to congruent stimuli in cued trials due to the fact that the orienting cue appeared on the exact same position of the target arrow facilitating the focus of attention to the target stimuli. However, in uncued trials the disengament and reorienting of attention to the target location would facilitate the processing of flankers due to a broadening of the focus of attention. The third interaction described was between alerting and orienting which consisted on a larger orienting effect in trials with a warning cue, which the authors explained as an acceleration of the orienting of attention induced by phasic alerting (see fig. 1.3).

Following the initial study of Callejas, Lupiañez and Tudela, several studies have shown that despite the relative independent neuroanatomy and distinct neuromodulator mechanisms, the attention networks present an interactive dynamic which modulates the information processing mechanisms that promote a coherent goal driven behaviour (Abundis-Gutiérrez et al., 2014; Callejas, Lupiàñez, Funes, & Tudela, 2005; Posner & Fan, 2008; Rueda, Fan, et al., 2004; Waszak, Li & Hiommel, 2010).

In the next section we will outline the neural basis and electrophysiological correlates of the executive attention network.

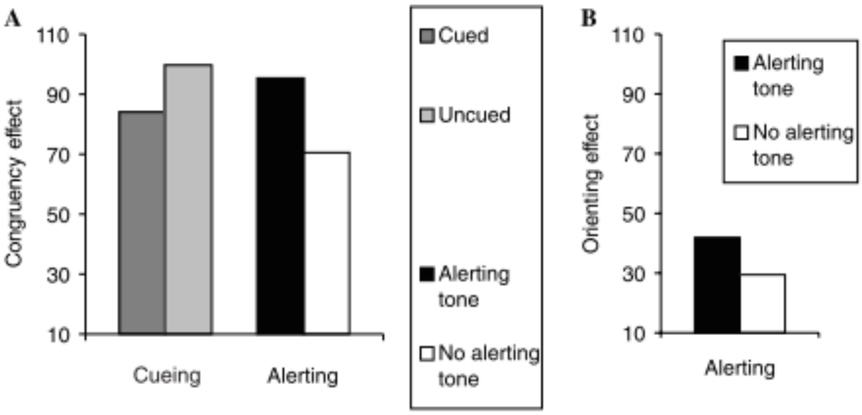

Figure 1.3. Interaction between attention networks. A) Congruency (incongruent – congruent trials) as a function of cueing (cue trials vs uncued trials) and alerting (trials with an alerting tone vs. trials without alerting tone). B) Cuing (mean RT for uncued trials – mean RT for cued trials) as a function of alerting (tone vs no tone trials). From Callejas et al. (2004).

1.5 Neural basis and Electrophysiological Correlates of Executive Attention

Advances in neuroimaging techniques and methodology have provided information that inform of the functional anatomy and neural dynamics of cognition in general, including cognitive control processes. Using the tasks described in the previous section, studies have been able to outline the neural dynamics and to localize different anatomical structures and brain networks that are related to the processes of conflict monitoring (Botvinick et al., 2001, 2004; Fan, Flombaum, McCandliss, Thomas, & Posner, 2003), inhibitory control (Aron & Poldrack, 2005;

Aron, 2011a; Chikazoe, 2010; Munakata et al., 2011; Sarrazin, Cleeremans, & Haggard, 2008) and performance monitoring (Hajcak, Moser, Yeung, & Simons, 2005; Steinhauser & Yeung, 2010; Ullsperger & Cramon, 2001; Ullsperger, Fischer, Nigbur, & Endrass, 2014; Yeung et al., 2004).

1.5.1 Neural Basis

Several neuroimaging studies using functional magnetic resonance imaging (fMRI) have pointed out to a set of frontal areas that are related to the top-down control of conflict processing (Botvinick et al., 2001, 2004; Carter & van Veen, 2007; Dosenbach et al., 2006; D. a Fair et al., 2007; Wendelken, Nakhabenko, Donohue, Carter, & Bunge, 2008). Botvinick et. al. (2001) presented a model that describes a brain network related to conflict monitoring and resolution. The authors suggested that the anterior cingulate cortex (ACC) was related to conflict detection and monitoring, while lateral frontal areas are involved in solving the conflict (Botvinick et al., 2001). Following this idea, Fan et. al. (2003) conducted a study using fMRI in order to track down the neural substrates of conflict processing by comparing the brain activation related to performance of three conflict tasks (Stroop, spatial conflict, and flanker tasks). Results show a common activation of the dorsal anterior cingulate (ACC) and the prefrontal (brodman area 10) cortices. By comparing results from the three different conflict tasks, the authors suggested that the activity of the ACC-PFC network is related to conflict monitoring, but do not execute operations to resolve the conflict. Instead, authors reported brain activation of different pre-frontal areas thought to resolve conflict trigger by each task (Fan et al., 2003).

Different authors have suggested a dual network architecture for implementing top-down control (Dosenbach et al., 2008). Support for this model comes from studies that aimed to examine control signals related to task set-maintenance, control initiation, feedback and adjustment activity. Dosenbach et. al. (2008) suggest that cognitive control is implemented by two functionally different, but complementary brain networks: the fronto-parietal and the cingulo-opercular networks. Cognitive control signals that potentially initiate and adjusts control on a trial-to-trial basis are related to the fronto-parietal network, that consists of the dorso-lateral pre-frontal cortex (dlPFC), inferior parietal lobule (IPL), dorsal frontal cortex (dFC), intra-parietal sulcus (IPS), precuneous and the middle cingulate cortex (mCC). This network seems to actively maintain task-relevant information to implement control adjustments that can be detected in cue-delay-target paradigms. The cingulo-opercular network provides stable set-maintenance over the entire task epoch, and includes the anterior pre-frontal cortex (aPFC), anterior insula/frontal operculum (aI/fO), dorsal anterior cingulate cortex/medial superior frontal cortex (dACC/msFC) and the thalamus (Dosenbach et al., 2008; D. a Fair et al., 2007). In contrast to the fronto-parietal network, the cingulo opercular network carries set-maintenance activity that extends across the performance of many trials within the task. Also, the model includes a set of cerebellar regions that are involved in processing errors by sending and/or receiving error information from one, or both, control networks in order to optimize performance. Dosenbach et. al. (2008) consider that this cerebellar areas are connected to the fronto-parietal regions through the dlPFC and the IPL, and to the cingulo-opercular network through the thalamus, which are regions that have been characterized by error related activity.

Petersen and Posner (2012) proposed that, even if these two models of executive control have similarities in terms of which anatomical structures are engaged in control processes, they propose different functional dynamic of the control system. While the cognitive control view (Botvinick et al., 2001, 2004) favours a single unified executive system in which lateral pre-frontal cortex provides top-down control signals guided by monitoring signals generated by midline structures, the dual network view (Dosenbach et al., 2008) proposes an independent functional dynamic of both systems by suggesting that the cingulo-opercular system acts as a stable background maintenance for task performance, and the fronto-parietal system shows activity related to start-cue signals and online adjustments within trials. Although both models explain considerable amount of data, studies from lesions in both humans and animals as well as studies related to the directionality of relationships between control processes, suggest that the dual network model presents a more suitable account of the executive control network (Petersen & Posner, 2012).

Another process that is linked to the executive attention network is inhibitory control. Several studies conducted with fMRI and Transcraneal Magnetic Stimulation (TMS), as well as studies with neuropsychological patients, indicate that a set on ventro-lateral prefrontal cortex and subcotrical structures underlie response inhibition processes (Aron, 2011b; Chikazoe, 2010; Munakata et al., 2011). These structures constitute a network of right lateralized brain areas that include structures in the Inferior Frontal Cortex (IFC) specifically the posterior inferior frontal gyrus (pIFG) and the inferior frontal junction (IFJ), structures in the dorso-medial frontal cortex specifically pre-suplementary motor (pre-SMA) and subcortical regions including the subthalamic nucleus (STN). When the system detects the stop signal it is relayed to the prefrontal cortex, where the inferior frontal and dorso-medial frontal regions process it. Within this area, it has been suggested that the IFJ as well as the pre-SMA are the structures that implement conscious detection and control, while the pIFG is in charge of implementing the inhibitory control (Chikazoe et al., 2009a; Hampshire, Chamberlain, Monti, Duncan, & Owen, 2010). Once the stop signal is processed, these frontal regions send a signal to the STN input structure of the basal ganglia, which leads to an inhibition of the basal ganglia output. In a recent study using diffusion-weighted imaging tractography (DWI), Aron et. al. (2007) showed that the IFC, the pre-SMA and the STN are directly connected through white matter tracts, which could underlie a "hyperdirect" inhibitory pathway of the basal ganglia in response inhibition tasks.

1.5.2 Electrophysiological Correlates

In order to study the temporal dynamics of cognitive control processes many studies have used electroencephalographic recordings (EEG).This neuroimaging technic allows the measurement of the neural activity evoked by a stimuli, also known as event related potential (ERP). One of the most frequently investigated electrophysiological correlate of cognitive control is the N2 component (Abundis-Gutiérrez et al., 2014; Mansfield, van der Molen, Falkenstein, & van Boxtel, 2013; Nieuwenhuis, Yeung, van den Wildenberg, & Ridderinkhof, 2003; Rueda, Posner, Rothbart, & Davis-Stober, 2004; Veen & Carter, 2001). This component is characterized by a negative deflection that peaks around 200 to 450 ms following stimulus onset and has a fronto-central distribution (N2, often also called N450; Checa, Castellanos, Abundis-Gutiérrez, & Rosario Rueda, 2014; Hanslmayr et al., 2008; Szűcs & Soltész, 2012). It has been suggested that this negativity reflects processes related to the selection of appropriate responses, inhibition of inappropriate responses and conflict monitoring processes (Falkenstein, Koshlykova, Kiroj, Hoormann, & Hohnsbein, 1995; Huster, Enriquez-Geppert, Lavallee, Falkenstein, & Herrmann, 2013; Kanske & Kotz, 2010; Mansfield et al., 2013; van Noordt & Segalowitz, 2012). It is also proposed that the N2/N450 component reflects cognitive control because when interference of a incongruent trial is resolved, the N2/N450 component is often enhanced relative to congruent trials (for a review, see Folstein & Van Petten, 2008). Source localization studies have found evidence that suggest that a possible generator of the N2/N450 component is the ACC (Veen & Carter, 2001).

Another component that has been considered a cognitive control index is the error-related negativity (ERN). This component is thought to reflect performance monitoring and is characterized by a negative deflection that peaks around 50–100 ms after the commission of an error (Dehaene, Posner, & Tucker, 1994; Gehring, Goss, Coles, Meyer, & Donchin, 1993). Yeung et. al. (2004) proposed that the response locked ERN is a component related to the stimuli-locked N2, because both reflects conflict monitoring in different stages of the processing of conflict. This claim is also supported by source localization studies that suggest that a common neural generator for the N2 and the ERN components in the ACC (Connell et al., 2007; Nieuwenhuis et al., 2003; Yeung et al., 2004).

In relation to response control, studies have identified two main components related with the inhibitory processes associated with the Go-NoGo task already described. Besides the N2 component studies have detected a component known as the P3, that peaks around 300 ms after onset of target stimuli (Comerchero & Polich, 1999; Kiefer, Marzinzik, Weisbrod, Scherg, & Spitzer, 1998; Nieuwenhuis et al., 2003; Roche, Garavan, Foxe, & O'Mara, 2005; Ruchsow et al., 2008). The morphology and the topography of this component suggest that it can be related to two different processes that have been related to the P3a and P3b component (Comerchero & Polich, 1999; Polich & Criado, 2006; Polich, 2007). The first component, the P3a, has a more fronto-central topography and it has been associated with the allocation of attentional resources that contribute to a rapid neural inhibition of on-going activity to facilitate transmission of task related information from frontal to temporo-parietal locations (Polich, 2007). The second component, the P3b, has been associated with the accumulation of evidence emerging from perceptual discrimination of an stimuli that inform decision-making processes in order to produce the most appropriate outcome (Polich, 2007; Roche et al., 2005; Ullsperger et al., 2014). The P3a and P3b components have been associated with generators located in the fronto-parietal network, the set of structures that have been associated with the inhibitory control network and with the more general domain of top-down cognitive control (Aron, Robbins, & Poldrack, 2004; Dosenbach et al., 2008; Falkenstein, Hoormann, & Hohnsbein, 1999; Munakata et al., 2011; Polich, 2007).

In the present chapter, I have introduced the idea of attention as a multimodal system which its related to the activity of three brain networks, focusing on the executive attention network which its related to cognitive control. I have explained some of the experimental approaches that are commonly used to study attention mechanisms and I have reviewed data about the common behavioral effects and underlying neural systems linked to the function of attention as a cognitive control mechanism. In the next chapter, I will discuss the developmental trajectory of the attention processes.

1.6. Development of attention and self regulation

From the developmental perspective, the ability to control and regulate behaviour and affective states plays an important role in children's socialization and personality development. There have been several studies that show a relationship between self-regulation and the maturation of the different attention networks, specially the executive attention network (Rothbart & Rueda, 2005; Rueda, Posner & Rothbart, 2005). Starting in infancy, children experience a transition from an automatic engagement of attention guided by external stimuli (exogenous control) into a more voluntary and controlled deployment of attention (endogenous control), which is many authors consider to be supported by the maturation of the brain areas that underlie self-regulatory mechanisms (Lozano, González, Antonio, & Carnicero, 2004; Rothbart, Sheese, Rueda, & Posner, 2011; Rueda, 2014).

Several studies suggest that during the first years of life the attention networks are less independent and work together in order to assist the regulation of behaviour and affect (Diamond, 2006; Rueda, et al., 2005). Evidence from different studies suggests that although each attention network is present to some degree in infancy, they experience different developmental trajectories. While alerting and orienting functions start to be present from the first few months of life and mature along childhood, rudimentary forms of executive attention only emerge at the end of the first year and appears to have a more protracted development extending through late childhood and adolescence up until young adulthood (Davidson, Amso, Anderson, & Diamond, 2006a; Rueda, Fan, et al., 2004; Zelazo, Craik, & Booth, 2004).

During the first year of life infants show increased ability to achieve and maintain a state of alertness (Colombo & Horowitz, 1987). This ability keeps developing in order to fine tune the processes that assist the preparation from alerting cues and the maintenance of that preparation (Morrison, 1982). The phasic and tonic aspects of alertness may influence RT when alertness is measured by comparing trials with and without warning cues. Previous studies about the developmental of phasic alertness show that age is associated with increased reduction in RT to stimuli that are preceded by alerting signals (Berger, Jones, Rothbart, & Posner, 2000; Mezzacappa, 2004). Similar to phasic alertness, the ability to endogenously sustain attention its strengthened with age, as shown by studies that use the Continuous Performance Test (CPT) to measure vigilance and sustained attention. For instance, Lin, Hsiao & Chen (1999) conducted a study using the CPT with a sample of 6–15 year-olds, and they found a progressive improvement in performance (measured with hits and false alarm rates) with age reaching the adult level around age 13. The fact that the level of alertness tends to fluctuate more in children than adults may be one of the aspects that explains age-related differences in speed of processing and accuracy commonly found in RT tasks.

Data from studies conducted with EEG supports the late development of the alerting network. Abundis-Gutierrez et. al. (2014) conducted a study using a child friendly version of the ANT task while recording the EEG with a sample of 4-6, 7-9, and 10-13 years-old children and adults. Even when there was no significant effect of age at the behavioural level, ERP's data revealed that, compared to older children and adults, children below the age of nine have poorer ability to process alerting signals. Compared to adults, 4-6 years-old children did not show any alerting cue-related amplitude difference in the AEP complex (associated to processing of auditory cue) before 300 ms. Moreover, from the components that are included in the AEP complex (P1, N1, P2), results showed that only the group of adults presented the N1 peak following the alerting tone, as well as a decrease in latency and amplitude of the P1 component with age (Abundis-Gutiérrez et al., 2014). All these data show that children in early and middle childhood show a poor early processing of warning signals indicating a still on going maturation of the alerting network.

The ability to orient attention undergoes a fast development throughout the first year of life, and is considered that this rapid development of the ability to voluntarily orient attention is related to the early development of emotional regulatory mechanisms (Rothbart et al., 2011). After infancy, it seems that the only aspects that continue to develop throughout childhood and adolescence are the ability to control the precision and the voluntary movement speed of attention. Using experimental tasks like Ponser´s paradigm, many studies have detected that despite the increase of orienting speed to valid cues during childhood, this orienting benefit effect shows no age related differences after 5 to 6 years of age (Enns & Brodeur, 1989). Besides this, when orienting is study with conditions that involved an invalid cue which required to voluntarily disengage and re-orient attention to the target location, studies show that the time to disengage is reduced with age, but the movement of attention toward the peripheral cue shows no change between 6-year-old children and adults (Akhtar & Enns, 1989).

Studies related to the visual orienting of attention have identified three components that are modulated by the presence of visual cue: the posterior P1 related to early visual processing, the N1 related to discrimination processes, and the P3 related to the process of disengagement and re-orienting of attention (Chica & Lupiáñez, 2009; Mangun, 1995; Vogel & Luck, 2000). Results from the study conducted by Abundis-Gutierrez et. al. (2014) show that the presence of a cue produces a consistent modulation of the amplitude of the early P1 component in all age groups. Additionally, results indicate that children below the age of seven do not show modulation of the N1 component, suggesting that attention continues to have an impact on subsequent stages of visual processing in older children and adults. Regarding the re-orienting of attention, results show that the modulation of invalid cue on the P3 component was larger for the youngest group of children suggesting that young children need to engage the fronto-parietal structures to a greater extent than adults, in order to disengage and re-orient attention to the target location. This data indicates that the underlying brain mechanisms of the orienting network are not completely efficient in children with less than 7 years of age.

Studies about the development of executive attention indicate that the processes related to this network experience a more protracted developmental trajectory starting to show evidence of the development of inhibitory control at the end of the first year of life (Davidson, Amso, Anderson, & Diamond, 2006b; Diamond, 2006; Rothbart et al., 2011; Rueda, et al., 2005; Rueda, 2013; Simonds et al., 2007). In the A-not-B task, infants are presented with a attractive object which is introduced into a display box with two different openings at the front edge (location A and location B). When the object was introduced in the location A the task of the children is to reach for the object at that location. This procedure it's repeated several times, which produces an automatization of the reaching process. After several trials of reaching in the location A, the experimenter place the object in the location B. Children 12 months and younger failed to reach the object when the object is changed from the original location (A. Diamond, 1991). After the first year of life, children are able to inhibit the reaching response to the previously trained location, and successfully reach the object in the new location. After the first year of age, executive control show a gradual development from 2 to 4 years of age measured by conflict inducing task like the Spatial Conflict Task, which induces conflict between the identity and the location of the object. Using this task, Gerardi-Caulton (2000) found that between 2 and 4 years of age children progress from almost not being able to perform the task, to a relatively good performance. The 2 year old group tend to perseverate on a single response, while 3 year olds performed with high accuracy and also showed the effect of slowing after having made a mistake (Gerardi-Caulton, 2000).

Studies conducted with conflict inducing tasks, like the Ericksen flanker task, present evidence of improvement efficiency of the executive control in pre-school years. Rueda et. al. (2004) show that the ability to resolve conflict evidence a strong development between 6 – 7 years (decrease in conflict scores) followed by a remarkable stability of conflict scores after 7 years. However, studies in which the difficulty of the conflict resolution is increased by other demands such as increasing load on working memory or including task switching rules evidence further development of conflict resolution between late childhood and adulthood. In a study conducted by Davidson et. al. (2006) they study the impact of increasing the difficulty of a spatial conflict task by manipulating memory load, inhibitory demands and cognitive flexibility (task switching rules). Results shows that the cost due to the need for inhibitory control was larger for children compared to adults, even under low memory load conditions the switching cost was larger in children 13 year old children and younger.

Data derived from studies using child friendly version of paradigms that asses conflict monitoring (such as the flanker task), together with the recording of the EEG, have provided information that help to elucidate the development of the underlying brain dynamics that support executive attention processes. Results from these studies show differences in the amplitude, latency and topography of the N2 component (Abundis-Gutiérrez et al., 2014; Jonkman, 2006; Lamm, Zelazo, & Lewis, 2006; Rueda, et al., 2004). Using a child friendly version of the ANT task Rueda et. al. (2004) reported that 4 year old children show a large negative deflection for the incongruent compared to the congruent conditions over mid frontal electrodes. In children, this frontal effect appears to be larger, more delayed onset (around 500ms after incongruent stimuli onset) and was sustained longer compared to the traditional N2 found in adults with the same task. Later in childhood, studies have shown that this negative deflection (N2) has a decrease in amplitude and latency with age, which appears to be related to the increase efficiency of the system to perform conflict monitoring (Abundis-Gutiérrez et al., 2014; Lisa M Jonkman, 2006; Lamm et al., 2006).

Besides conflict monitoring, there has also been an interest in studying the development of the neural dynamics related to response monitoring. As discussed earlier, the ability to monitor our performance and to detect errors is associated to the executive attention system and it has been suggested that it is indexed by a response-locked ERP named Error Related Negativity (ERN). Generally larger amplitudes of the ERN are related to a greater efficiency of the error detection system (Davies, Segalowitz, & Gavin, 2004; Luu, Tucker, & Makeig, 2004; Santesso, Segalowitz, & Louis, 2010; Steinhauser & Yeung, 2010; Yeung et al., 2004). Davies, Segalowitz and Gavin (2004) presented evidence suggesting that young children are less likely to present an ERN than adults, and that the amplitude of the ERN progressively increases during childhood up until mid adolescence.

Together with electrophysiological data, neuroimaging techniques have contributed to the study of the development of attention control. Using the fMRI technique several studies have presented evidence that indicating that cognitive functioning is supported by different functional networks that exhibit local and strong connections during infancy (Fair et al., 2009; Power, Fair, Schlaggar, & Petersen, 2010). Throughout childhood short distant connections weakens while long distant connections become strongest, suggesting that basis for a more efficient cognitive system is the increased communication between different brain areas (Fair et al., 2009;Fair et al., 2007; Power et al., 2010). Supporting this evidence, Casey, Tottenham, Liston & Durston (2005) reviewed evidence from multiple neuroimaging studies indicating that throughout childhood there is a widespread engagement of cortical areas related to higher cognitive processes, which become more focalized as the system becomes more specialized and mature. This maturational change suggests that increase in efficiency of cognitive control mechanisms is supported by the specialization of different brain related areas.

The behavioural and neuroimaging data presented earlier about the development of executive attention supports the notion that executive control experience a protracted development that extend throughout middle childhood, reaching adult like levels of efficiency until late adolescence. As was outlined before, executive attention network has been associated with the processes that underlie the ability to regulate, control and organize our thoughts, therefore it is important to understand the normal developmental trajectory of these processes to be able to comprehend how different factors (e.g. temperament, genetics, education) may influence this trajectory.

In this section we have outlined the "normative" development of the executive control mechanisms throughout childhood. In recent years there has been a considerable growth in studies that try to understand how environmental factors may influence the emergence, development and strengthening of cognitive processes. In the next chapter we will discuss some of the evidence about the influence of training interventions in brain plasticity and the enhancement of efficiency of the Executive Functions.

1.7 Plasticity and training interventions: influence of environmental factors in the development of Executive functions.

Throughout developmental there are periods in which a neural system is maximally sensitive to environmental influences, these time points are refer to as *sensitive periods* of development (Mackey, Raizada, & Bunge, 2013; Rice & Barone, 2000). The beginning and end of these sensitive periods varies across functional domains (e.g. vision, hearing, attention, language) and is closely related to the maturation of the underlying brain mechanisms (B J Casey, Giedd, & Thomas, 2000; Gogtay et al., 2004).

Although these sensitive periods of development present time-points in which neural and cognitive systems are maximally sensitive to environmental input, it seems that brain plasticity is not restricted to these time-windows. In fact, there is now substantial evidence that suggest that plasticity is a property of the brain that may be present throughout the entire life. Evidence gathered from studies related to cognitive interventions indicate that several neural and cognitive systems are susceptible to the influence of training (Jaeggi, Buschkuehl, Jonides, & Shah, 2011a; Jolles & Crone, 2012; Moore, Gruber, Derose, & Malinowski, 2012; Rueda, Rothbart, et al., 2005; Yi-Yuan Tang & Posner, 2014). Thus, the emergence and strengthening of cognitive and neural systems can be related to the interplay between development (or *experience-expectant*) and learning (or *experience-dependent*) processes (Galván, 2010; Mackey et al., 2013). The emergence and maturation of the different sensory and cognitive systems represent changes that follow typical development, which is driven by experience-expectant processes. While the plasticity that results from learning, represents neural changes that are associated with experiences that are specific to each individual (e.g. learning, training, rehabilitation) and appear to be driven by experience-dependent processes (Galván, 2010). The understanding of how the interplay between development and learning influences the emergence, maturation and improvement of cognitive control mechanisms may provide information to assist the design of more specialized and efficient educational and cognitive interventions. Therefore, it is important to assess the impact that cognitive training interventions have over executive control mechanisms and higher order functions, as well as the features that contribute to their beneficial outcome.

In recent years there has been an increased interest in studying the effects of cognitive training by means of computerized interventions designed to improve the efficiency of the different cognitive control mechanisms (for reviews see: Jolles & Crone, 2012; Karbach & Unger, 2014; Melby-Lervåg & Hulme, 2013; Shipstead, Redick, & Engle, 2012). In general, this research has focused on answering empirical questions about the trained functions and the processes that supports the changes produced by training, as well as on understanding the important factors in designing effective training interventions.

Cognitive training can be defined as the process of improving cognitive function by means of practice and/or intentional instruction (Jolles & Crone, 2012), and has focus primarily on training processes related to executive attention (Rueda et al., 2012; Rueda, Rothbart, et al., 2005), cognitive flexibility (Karbach & Kray, 2009; Kray, Karbach, Haenig, & Freitag, 2011) inhibitory control (Millner, Jaroszewski, Chamarthi, & Pizzagalli, 2012) and working memory (Jaeggi, Buschkuehl, Jonides, & Perrig, 2008; Jolles, van Buchem, Crone, & Rombouts, 2013; Klingberg, 2010; Olesen, Westerberg, & Klingberg, 2004). The programs are designed as computerized exercises build upon the principles of traditional experimental paradigms used for research in cognitive psychology. The main principle behind the training is that through repetitive practice, combined with the gradual increase of level difficulty, there should be an improvement in the efficiency of cognitive processes that need to engage while performing the exercises.

In order to assess the effectiveness of training there are two main effects that can be examined: *near transfer* and *far transfer* (M Buschkuehl & Jaeggi, 2010; Jolles & Crone, 2012; Klingberg, 2010). Near transfer refers to the effect that training produces in the cognitive processes that are directly engaged in the training exercise (e.g. inhibitory control, working memory, etc.), whereas far transfer refers to the effect that training has on processes that are not directly recruited by the exercise. Even though it is desirable that training programs would result in generalized effects, reflected by far transfer, there is still a lack of knowledge about which factors promote far transfer. It has been suggested that one of the underlying factors of far transfer may be the overlap of brain structures that are related to the processes recruited for the effective execution of the training and evaluation tasks (Jaeggi et al., 2008; Kray et al., 2011; Rueda et al., 2012).

A recent study conducted by Millner et. al. (2012) shed light on the factors that promote near transfer effects. Millner et. al. (2012) implemented a 3-session training program with adults (mean age 27) aimed to train inhibitory control processes with the Simon (spatial conflict) task (Holmes & Pizzagalli, 2011) and with an emotional Go-NoGo (Chiu, Holmes, & Pizzagalli, 2008). Results were assessed using a flanker task (Eriksen & Eriksen, 1974), emotional Face Stroop task (Etkin, Egner, Peraza, Kandel, & Hirsch, 2006), where participants should identify the affect of faces with fearful or happy expressions that had either “fear” or “happy” written in front, and a two choice reaction time. EEG was recorded in order to analyse transfer effects and the underlying brain mechanisms that may promote them. In this study, the two tasks related to emotional conflict were included in order to detect training-related improvements in affective regulation. Following training in inhibitory control, participants demonstrated improvement in behavioural performance on the flanker task, shown as faster RTs on incongruent trials while maintaining similar accuracy. Also, event-related potential analyses showed a reduction in N2 amplitude for incongruent trials with training. Moreover, participants showing the greatest pre-post decrease in the N2 amplitude displayed the largest reduction in RT conflict effect.

Previous studies (Yeung & Cohen, 2006) have shown that smaller N2 amplitude is related to a decrease in processing of the irrelevant stimulus dimension of the trial (i.e. better attentional control). Millner et. al. (2012) suggested that a possible explanation for the reduction of the N2 may be related to a practice-related enhancement of conflict resolution automaticity. Cohen et. al. (1992) argue that automatic and controlled processes exists within a continuum and that due to practice or training activities that previously required control become more automatic. Therefore, the pre-post training reduction in N2 and RT suggests the possibility that attention became more automated resulting in less conflict within incongruent trials.

Regarding the effects of training in affective regulation, results of the Millner et al. study show no training-related improvement in resolving emotional conflict. Authors suggest that a possible explanation for the lack of transfer effect is due to the fact that the task used for training (emotional Go-NoGo) relies on different interference resolution mechanisms, which are also supported by different brain structures (Millner et al., 2012). A previous study with the emotional Go-NoGo task reported activation of the rostral part of the ACC (rACC) when comparing emotional with non-emotional stimuli, but activation of the ventrolateral frontal cortex in response to trials that require inhibitory control (Chiu et al., 2008). As has been described in a previous section, inhibitory control processes elicited by the Go-NoGo task have been related to the activation of the ventrolateral frontal cortex (Aron et al., 2004), whereas conflict elicited by stroop-like paradigms are related to activation of the ACC (Carter & van Veen, 2007). This suggests that the inability to detect transfer of inhibitory control training with an emotional Go-NoGo task to performance of the Emotional Face Stroop task may be related to the fact that both conflict effects engage different brain structures. This data supports the hypothesis that the overlapping of engaged brain structures, between trained and evaluated processes, is a factor that underlies transfer. One of the main deficits of this study is the lack of a control group, therefore it is difficult to be certain that the observed improvements were the result of specific changes in cognitive control, or whether they reflect an improvement of an unspecified more general mechanism.

Another study that presents evidence about near and far transfers effect was conducted by Karbach and Kray (2009). In this study, the authors compared the effects of a 4-session task-switching training program in a sample formed by children (9 yrs), young adults (22 yrs) and older adults (68 yrs). They divided the subjects into different training groups that trained task switching with different switching loads. Near transfer effects were measured by extracting indexes for mixing-costs and switching-costs, from the task-switching paradigm. Switching-cost were measured as the difference in mean performance between single-task and mixed-task blocks, and mixing-cost as the difference between no-switch and switch trials within mixed-task block (Karbach & Kray, 2009). Far transfer effects were assessed with a cognitive battery, which included behavioural measures of inhibitory control, spatial working memory, verbal working memory and fluid intelligence. Results of this study, evinced substantial near transfer effects, consistent on a pre-test to post-test reduction of mixing-costs and switching-costs for the task-switching training group. Due to the training design, this result suggests that the training of cognitive control processes, and associated transfer effect, is not merely mediated by automatization of single-task components. Also, when analysing the differential near-transfer effects in each age group, results revealed that the transfer effect in the level of mixing-costs was more pronounced in children and older adults, suggesting that the processes of task-set maintenance and selection were improved mostly in these age groups (Karbach & Kray, 2009). On the other hand, results related to far transfer effects showed that task-switching training produced improvement in performance for measures of interference control, verbal and spatial working memory tasks, and intelligence. Karbach and Kray (2009) suggest that this far-transfer effect may be promoted by task-switching training because training exercises require the engagement of different cognitive control processes for a correct performance. Training exercises require constant engagement of interference control due to the high ambiguous features of the stimuli, and maintenance of task-set because subjects had to perform two tasks rather than only one. These data provide evidence that supports the idea that far-transfer effects are based on the training of overlapping cognitive control processes.

Other studies have tried the processes of brain plasticity underlying cognitive training. Olesen, Westerberg and Klingberg (2004) conducted a study in which they assessed the influence of training in activation patterns of brain structures related to working memory. They used a 5-week training program, which included tasks related to visuo-spatial working memory, digit span and letters span. In order to evaluate training effects in brain dynamics, participants were scanned before and after training while performing a working memory task. Subjects were also assessed with a battery of neuropsychological tests that included the span board task, a visuo-spatial working memory task, fluid and non-verbal reasoning tests, and the stroop interference task. In general, behavioural results showed improvements in performance in the spatial stroop, memory span, fluid intelligence, and the working memory task performed during the scan session. Moreover, neuroimaging results showed increased activation of pre-frontal (middle frontal gyrus) and parietal (intra-parietal, and inferior parietal) regions (Olesen et al., 2004). These results suggest that the improved efficiency of the trained processes was due to a pre to post training increase of activation in regions involved in the trained processes.

Jolles et. al. (2013) conducted a study in which they assessed the impact of a 15-sessions working memory training program in resting-state functional connectivity patterns using fMRI (rsfMRI), with a sample that included children (12 yrs) and adults (22 yrs). They focussed on two different brain networks, the fronto-parietal network related to working memory processes, which includes the middle frontal gyrus (MFG), lateral pre-frontal cortex (PFC), dorsal anterior cingulate cortex (dACC), supplementary motor cortex, superior parietal cortex and supramarginal gyrus; and the default mode network including the medial pre-frontal cortex (medial PFC), posterior cingulate cortex (PCC), precuneus, and lateral parietal cortex (Corbetta et al., 2008; Jolles, Grol, Van Buchem, Rombouts, & Crone, 2010; Mantini, Perrucci, Del Gratta, Romani, & Corbetta, 2007). Results of the study with the adults sample revealed that functional connectivity within the fronto-parietal network increased after practice and was related to the increase in accuracy in task performance shown by participants, whereas the connectivity pattern within the default network presented a decrease in connectivity that was negatively related to the increase in task performance. In order to explain the observed functional connectivity changes after working memory training, Jolles et. al. (2013) suggest three different possibilities that are not mutually exclusive. First, it has been suggested (Fox & Raichle, 2007) that functional connectivity represents a record of previous use, showing increased correlations between regions that have frequently presented patterns of co-activation, which could indicate that the increased functional connectivity in the fronto-parietal network may reflect the fact that these regions have been co-activated repeatedly during practice. Second, it might be possible that these connectivity changes may not only reflect co-activation in the past (during training period) but also that it reflects the expectation about co-activation in the future (Raichle, 2006). A third explanation could be that correlated activity may have a direct role in the modulation and coordination of information processing, thus reflecting changes in task preparation processes.

In contrast to the results found with adults, there was no evidence of training-related changes in rsfMRI patters in children despite the fact that 12-year-old children presented similar functional connectivity patterns to those of adults in both brain networks at pre-test. Jolles et. al. (2013) suggest that this data argues against the interactive specialization hypothesis (Johnson, 2011) which predicts more plasticity in less specialized brains, instead, they argue that the lack of training effects could be explained either because of a) maturational constrains related to the immature brain structure, b) the exposure that children have in tasks that engage working memory processes in school, c) or because of an immature planning or preparation processes concerning upcoming tasks (Jolles et al., 2013). Regardless of these explanations, it is important to notice that the sample size used for this study was 9 children, which could result in a lack of power to find practice effects at a network level.

Rueda et. al. (2005) conducted study where they evaluated the effects of executive attention training in pre-school children. A sample of 4- and 6- year old children, divided in trained and control groups, participated on a 5-day attention training program consisting of exercises designed to train stimulus discrimination, conflict resolution and inhibitory control. Training related effects in attention processes were assessed using the ANT task adapted for children (Rueda, et al., 2004) while recording brain electrophysiological activations with a high-density EEG system. In order to detect far-transfer effects, measures of fluid and verbal intelligence were also taken. Even if participants showed a general reduction in RTs and commission of errors after training, there was no training related reduction of conflict interference effects in either group. In contrast, training effects were observed in measures of fluid intelligence. Besides, electrophysiological data showed that training had a specific effect on the scalp topography of conflict-related activations that was similar to the influence of development, which was only observed for trained children (Rueda, et al., 2005). The trained group of 4-year-old showed a prefrontal conflict effect (i.e. more negative amplitudes for incongruent compared to congruent trials) at the time-window of the N2 component. This prefrontal effect was found in the untrained group of 6-year-old. Moreover, trained 6-year-old children showed topography of conflict related activation that resembled the one shown by adults while performing the same task. The adult-like pattern of activation consist of a faster N2 component with a more dorsal-frontal distribution, which has been related to activation emerging form the dorsal portion of the ACC (Van Veen & Carter, 2002). Taken together, these data show that attention training produces effects that complement that of normal development in a way that may promote a faster maturation of the underlying brain structures.

Attention training also produces far transfer effects by promoting the improvement of fluid intelligence scores. According to the suggestion that far-transfer effects are related to the overlapping of underlying brain structures underlying trained and evaluated processes, several studies have shown that the brain regions recruited while performing reasoning tasks as the ones presented in most intelligence tests greatly overlap with structures related to cognitive control mechanisms (Duncan & Owen, 2000; Duncan, 2000).

In order to replicate the effects found by Rueda et. al. (2005) and to assess the durability of the training effects, Rueda et. al. (2012) conducted a second study in which they evaluated training effects on behavioural measures and brain activation immediately after the training, as well as in a two-month follow-up session. This study used a similar training program as the one used by Rueda et. al. (2005) with 5 year-old children, but using an increased number of sessions and a larger number of training exercises. The program was designed to train processes related to anticipation, attentional focussing, conflict resolution, inhibitory control and sustained attention. As in the previous study, effectiveness of the training program was assessed using the child version of the ANT task, as well as with a measure of both fluid and verbal intelligence. As in the previous study, data revealed a general improvement in task performance evinced by a reduction in RTs and percentage of commission of errors. This improvement was similar to both groups (experimental and control), showing that behavioural indexes of the Child ANT task may not be sensitive enough to capture training-related changes. Rueda et. al. (2012) suggested that this lack of sensitivity may be related to a high variability of RTs in pre-school age children, and/or, that the children may have reached a high performance level in the task due to a mere effect of practicing the task. However, as in the prior study, a significant increase in fluid intelligence following intervention was obtained by the trained group, which was still observed in the two months follow-up session. These results support data from other studies that also found that interventions designed to train cognitive control produce an improvement in fluid intelligence measures (Bergman et al., 2011; Jaeggi et al., 2008; Thorell, Lindqvist, Bergman Nutley, Bohlin, & Klingberg, 2009), and that this transfer effect may be sustained even after the training intervention is over.

Neuroimaging data show that training modulated the latency and topographical distribution of the flanker's congruency effect. Replicating results from Rueda et al. (2005), the effect of the flankers in the time window of the N2 component presented an early onset and a more dorsal-frontal distribution for the trained group compared to untrained peers. Moreover, this training related change was maintained two months later (Rueda et al., 2012).

In conclusion, training studies have shown the potential benefit of implementing exercises to potentiate the efficiency and maturation of cognitive control processes with different populations. Even though these results look promising, there is still a lack of connection between these training strategies and educational approaches, which may provide models and tactics that would help to improve the impact of training interventions. One such model is the model of Metacognition (Efklides, 2008; T. Nelson & Narens, 1990), which will be outlined in the next chapter.

1.8 Metacognition: another way to conceptualize cognitive control and self-regulation.

Metacognition (cognition about cognition) has been defined as any knowledge, affective experience and/or cognitive activity that takes as its object any aspect of the cognitive activity in order to supervise, evaluate, monitor and control one's own cognitive processes, perceptions, thoughts, memories, and actions (Efklides, 2008; Flavell, 1979, 2000; Shimamura, 2008). The concept of Metacognition emerged from the research tradition of learning and education (Larson & Gerber, 1987; Monitoring, 1997; T. Nelson & Narens, 1990; Winne, 1996), and has evolved parallel to the concept of cognitive control and self-regulation until the past decade, in which a broader consensus started to emerge relating metacognition to the monitoring and control of cognition, while self-regulation was linked to a broader aspect of monitoring and control of all different aspects of human experience (e.g. emotional, social and motivational) (Whitebread, Almeqdad, Bryce, & Demetriou, 2010).

One of the first models of metacognition, the model of Nelson and Narens (1990), was developed specifically to address the cognitive processes that are important for learning and memory. In this model, it is proposed that metacognition makes learning more efficient by influencing behaviour in many stages of the memory process, from stimulus encoding to the ultimate retrieval of information (Shimamura, 2008).

The model of Nelson & Narens (1990) describes metacognition as the interplay between two levels of information processing, the object-level and the meta-level. The meta-level is continuously updated by bottom-up information obtained from monitoring the object-level, and in return controls the object-level by providing top-down input to initiate and terminate actions preformed by the object-level. From this model, research on metacognitive processes has identified three main different components that arise from, and act upon, the interaction between the meta-level and the object-level: a) Metacognitive Experiences (ME), b) Metacognitive Control or Regulation (MC), and c) Metacognitive Knowledge (MK) (Efklides, 2008; Fernandez-Duque, Baird, & Posner, 2000; Flavell, 1979; A. P. Shimamura, 2008). The conceptualization of metacognition as a multifaceted mechanism allows the integration of cognitive and affective experiences into a unified construct of cognitive control. Specifically, metacognitive experiences and metacognitive knowledge are related to the monitoring aspect of metacognition, while metacognitive regulation serves as a control function that involves initiation and/or termination of cognitive processes (Efklides, 2008).

Metacognitive Experiences (ME) are online feelings, judgement, estimates, and thoughts people are aware of during task and includes awareness of task features, fluency of cognitive processing, progress toward the goal set, the effort exerted on cognitive processing, and the outcome of processing (Efklides, Volet, Sansone, & Pekrun, 2005; Efklides, 2006, 2008). Efklides (2006) suggests that the importance of these online subjective responses to the task lies in the fact that they form the interface between the person and the task and provide the basis for control decisions during task processing, as well as after it. These ME are products of non-analytical, non-conscious metacognitive monitoring processes and are related to self-regulated learning. Feeling of Knowing (FOK), Feeling of Confidence (FOC), and Judgement of Learning (JOL) are examples of ME (Efklides, 2006; Meiser & Sattler, 2007; Shimamura, 2008).

Metacognitive Control (MC) refers to processes that coordinate cognition by imposing top-down regulation of information processing (Fernandez-Duque et al., 2000; Shimamura, 2000), and includes the deliberate use of strategies (i.e. procedural knowledge) in order to control cognition (Efklides, 2008). Also known as Metacognitive Regulation, this facet of metacognition has been linked to aspects of executive functions particularly because both enable top-down modulation of cognitive processes necessary to produce voluntary action. Metacognitive Control (MC) and Executive Functions (EF) are linked to cognitive processes such as selective attention, working memory, conflict resolution, task switching, inhibitory control and cognitive monitoring (Fernandez-Duque et al., 2000; Shimamura, 2000). It has been suggested that MC processes are also associated with different brain structures such as the anterior PFC, dorso and ventro lateral PFC, dorso and ventro medial PFC, orbito frontal cortex and the frontal eye field, that have also been identified as structures that underlie processes related to executive functions (Botvinick, Cohen, & Carter, 2004; Fernandez-Duque, Baird, & Posner, 2000a; Posner & Rothbart, 1998; Shimamura, 2008).

In order to characterize the relation between MC and EF, Shimamura (2000) identified four aspects of executive control that couple with aspects of metacognition: a) selecting, the ability to focus attention to stimulus events or activate memory representations; b) maintaining, which relates to the ability to keep active information in working memory; c) updating, that refers to the ability to modulate and rearrange activity in working memory; and d) rerouting, which refers to the ability to switch from one cognitive process or response set to another. By establishing these connections it is possible to integrate both constructs, providing the basis that allows sharing of empirical evidence between research traditions in order to bring forth a more comprehensive account of behavioural and cognitive control mechanisms.

Metacognitive Knowledge (MK) consists primarily of knowledge or beliefs about what factors and variables interact to affect the course and outcome of cognitive processes (Flavell, 1979). In other words, MK refers to what individuals know about their own cognition or about cognition in general (Schraw & Moshman, 1995). Schraw and Moshnam (1995) divide metacognitive knowledge into three kinds of metacognitive awareness: Declarative, Procedural and Conditional knowledge. Declarative knowledge includes knowledge about oneself as a learner and about the factors influencing one's performance. Procedural knowledge refers to knowledge about the execution of procedural skills. And finally, conditional knowledge, concerns to when and why to apply various cognitive actions (Schraw & Moshman, 1995). Metacognitive Knowledge is thus considered an important aspect of cognitive control because it allows the creation of a model of one's own cognition that supports the awareness of our cognitive abilities (i.e. declarative knowledge), enables the organization of proceedings to be executed (i.e. procedural knowledge) and for the correct implementation of this proceedings (i.e. conditional knowledge) in order to accomplish task goals.

Metacognitive knowledge its continuously updated and enriched by the information coming from the conscious monitoring of cognition. This is accomplished by observing the results of one's own and other people's actions, becoming aware of our metacognitive experiences, as well as by interacting and communicating with others (Efklides, 2008). Thus, Efklides (2008) suggests that language plays an important role in the development and improvement of MK because through language a person is able to communicate the content of their awareness, reflect, draw inferences, and make attributions about the relations between inner states and observable behaviour and action outcomes. Also, language and reflection enable people to analyse and compare their knowledge with that of others, allowing them to form explicit theories about knowledge and cognition. The central aspect of language in the development of MK suggests that certain models of cognition are socially shared and emerge through social interaction, making MK susceptible to education and training.

If MK is a key component of cognitive control and regulation, then it would be important for any program that aims to enhance regulation abilities (e.g. education or training programs) to include features that foster the emergence and strengthening of the awareness and knowledge needed to effectively engage control processes. As has been proposed by Efklides (2008), Metacognitive Knowledge can be transmitted through social interaction by means of language, which suggests that MK can be trained. In the next chapter we will present some ideas from the historico-cultural theory of development of Vygotsky (Vygotsky, 1978a). This theory established important links between the development of executive control mechanisms, social interaction and language, which we considered important elements that could foster the emergence of metacognitive knowledge in the context of a training intervention.

1.9 Social interaction and development of self-regulation: The Vygotskian approach

In the cultural-historical model developed by Lev Vygotsky, the construct "Higher Mental Functions" and the idea of psychological systems are used to refer to processes related to EF and self-regulation, due to the fact that both enable the control and regulation of behaviour and cognition (Bodrova, Leong, & Akhutina, 2011; Fernyhough, 2009). For vygotskians, higher mental functions and executive functions are self-regulated, mediated and learned mental functions that emerge, not simply by the natural maturation of the brain and cognitive processes, but also based on the process of his interaction with the environment and communication with adults (Bodrova et al., 2011; Luria, 2002). Through this communication children acquire a set of tools, mostly of linguistic nature, that allows them to gain control and support self-regulation of behaviour and cognition. Therefore, Vygotsky suggested that a milestone in the development of higher mental processes happens when children acquire language as a tool for representing the world (Vygotsky, 1978; Vygotsky, 1978). Language has an instrumental value for cognition because it allows the child to abstractly manipulate perceptual information and assist cognitive processes in order to produce actions directed to accomplish particular goals. For Vygotsky (1978), the instrumental value of language is clearly seen during development when, for example, a child can focus his or her attention by means of labelling objects or can direct his/her problem-solving activities by engaging in external speech, which later becomes internalized into private speech.

The cultural-historical approach suggests that throughout development it is neither the functions nor their structure that change, but it is the relations and connections between the functions which become changed and modified. This process creates what is called a new *psychological systems*, which were unknown at the preceding stage (Bodrova et al., 2011). Psychological systems comprise mental and physiological processes that are complex and dynamic in nature.

During childhood, higher mental functions undergo a sequence of developmental-stages that establish regulatory processes. These progress from socially-shared to individually-internalized functional systems. The first stage, the *inter-mental stage*, is characterized by the fact that the initiation and execution of the action is distributed between two persons. Next, the *extra-mental stage*, occurs when the child issues commands to himself or herself and then executes these commands. Finally, the *intra-mental stage*, is characterized by the fact that the voluntary action is formed, and the formation of a new structural-functional system emerges (Vygotsky, 1997). These stages are dependant on the use of language as a tool for the transmission, explicit articulation, and final internalization of the necessary regulatory commands. Luria (2002), a former student of Vygotsky, explained that “when communicating with adults, reorganizing his/her behaviour on the basis of objective activity and speech, and gaining knowledge, a child not only acquires new forms of relationships to the external world, but also works out new ways of regulating his/her behaviour and establishes new functional systems enabling him/her to master new forms of perception and recall, new ways of thinking, and new methods for organizing voluntary actions" (pp. 19). The nature of the relation between components of the resulting structural-functional system is determined by the nature of social mediation existing primarily in the form of language (Bodrova et al., 2011).

This approach on the systemic structure of higher mental and executive functions provides practical implications that support the design of interventions focused on foster the emergence of these self-regulatory processes. Taking into account that EFs are developed based not only on the maturation of cognitive processes and their underlying brain structures, but also on variables present in the social context, it is important to understand how the social mediation provides the necessary tools and experiences that promote their development.

1.10 The Zone of Proximal Development and Scaffolding intervention

Vygotsky (1978) proposed that the influence that the external agents produce on the development of children's higher mental functions is exerted at what is called the *Zone of Proximal Development* (ZPD). This was defined as "the distance between the actual developmental level, as determined by independent problem solving, and the level of potential development, as determined through problem solving under the adult guidance or in collaboration with more capable peers" (Vygostsky, 1978, pp. 86). Therefore, the ZPD describes the distance between the level of development already reached by natural maturation of cognition and underlying brain structures, and the potential development that could be possible through guidance or in collaboration with more capable individuals. When a teacher or parent assists the child when doing a task, they establish a social interaction through which they provide scaffolding within this zone of proximal development that enables the child to perform at a higher level (David Wood, Bruner, & Ross, 1976).

Scaffolding is thus a tool that facilitates learning. According to Wood et. al. (1976) scaffolding has six key functions: 1) engaging the child into the task in a meaningful way, 2) reducing the components of the task in order to make it manageable for the child, 3) maintaining the child in the task, 4) shedding light into the main components of the task, 5) reducing the likely frustration of trying a task that may be too difficult; and 6) providing a model of the solution method for the child. Scaffolding interactions should be designed in order for each child to fall within his/her individual ZPD. This type of interaction support the skills and knowledge that are just about to emerge in the child, which in turn helps children to move from being assisted by an adult in performing a new task to being able to perform it independently (Bodrova et al., 2011; Bodrova & Leong, 2007; David Wood et al., 1976). When providing scaffolding, the adult does not make the task easier, instead he/she provides assistance in the first stages of the task, then gradually withdrawing this support as the child masters the newly developed skills.

Even though initially the term scaffolding was used in relation to problem-solving learning, there is now evidence that scaffolding interventions are also applied for the development of cognitive processes. Some research has shown that children can learn how to regulate attentional processes through interactions with the parents (Bronfenbrenner, 1999; Robinson, Burns, & Davis, 2009; Rogoff, 1990). The development of attention regulation abilities is fostered by socio-cognitive transactions by which a more capable and experienced adult helps children learn to direct their attention to the key elements of a task, while ignoring less relevant information within the environment (Rogoff, 1990).

A study conducted by Kopp (1987) evinced that specific types of control techniques used by caregivers influence children's self-regulation abilities. The study was conducted with a sample of middle income families, and shows that mothers who encourage independence were more likely to have children who were rated low in impulsivity, inattention and hyperactivity, and high on self-control measures (Kopp, 1987). In a recent study, Robinson et. al. (2009) examined the impact of maternal scaffolding in children´s attention regulation abilities in a sample of preschool children from low-income families. The authors of the study were interested in assessing how children regulate their attention processes in the presence of their mother and when they are alone, and to examine how specific behaviours of the mother may relate to children's abilities to regulate their own attention during a parent-child and child-alone puzzle-matching task. Results of the study show that higher proportions of self-regulated attention (measured by self-regulated gazes) during the parent-child puzzle task were related to higher accuracy in the child-alone puzzle task, only for the group of children whose mothers provided higher amount of scaffolding. This results suggest that children who had received more scaffolding may have better learned attention regulatory abilities, demonstrating more competence in their independent puzzle-matching performance (Robinson et al., 2009).

In summary, cognitive control and self-regulation processes are important aspects that are related with a better social-emotional development, school achievement and the prevention of adverse psychopathology. Throughout childhood, the development of these cognitive processes undergoes different sensitive periods that are related to naturally normative factors and are also susceptible to experience-related influences. One of the most important environmental influences on cognitive development it's exerted by social interaction with the use of language, which constitutes an important tool for improving cognitive control abilities. Several studies have shown that the efficiency of different cognitive processes may be improved by means of cognitive training interventions, which may provide a beneficial influence in the strengthening and development of cognitive control mechanisms throughout childhood. Therefore, in the present dissertation work we will try to further study the developmental trajectory of the attention networks, as well as to study the influence of environmental factors (such as cognitive training) in the development of executive attention.

Experimental Series.

Chapter 2.

Research Question and Hyphotesis.

2. Questions and Hypotheses

The evidence reviewed in the introduction indicates that attention processes are part of the cognitive control mechanisms implicated in the ability to regulate cognition and behaviour in a flexible and controlled way. These cognitive abilities have been proven to be important to many aspects of children's development. For instance, the efficiency of the executive attention network has been related to school competence and socialization (Purificación Checa, Rodríguez-Bailón, & Rueda, 2008; Rueda et al., 2010), emotional regulation (Simonds et al., 2007), and to the prevention of developmental psychopathologies, such as ADHD (A. Diamond, 2005; Posner & Rothbart, 2000; Posner, Rueda, & Kanske, 2007a). Therefore, it is important to have a thorough understanding of the developmental trajectory as well as the environmental factors that influence the development of attention processes in order to be able to precisely identify possible impairments as well as to design more effective intervention programs.

The goal of the research presented in this dissertation is twofold. First, we aim at having a better understanding about the developmental trajectory of attention. We are interested in studying the development of attention networks and its interactions throughout childhood. Second, to assess the influence of environmental factors and social interaction in the development of executive attention, we are interested in studying the impact of an attention-training program in pre-school children. As part of this goal, we aimed at comparing the effects of intervention with and without metacognitive scaffolding. In order to address these topics, we conducted two experimental series aimed to gather information that would help us to answer the following experimental questions.

2.1. Development of attention:

2.1.1. Does attention networks interaction emerges throughout childhood?

Does attention networks interaction emerge throughout childhood, or are they a dynamic property already embedded in the attention system? In order to address this question we examined the developmental course of attention networks in childhood using a modified version of the child ANT task.

The ANT is an experimental paradigm that provides measures of the efficiency of the alerting, orienting and executive attention networks within a single task. To examine the developmental course of the three attention networks in Posner's model, Rueda, et. al. (2004) adapted the original ANT task in order to make it more child friendly by replacing the arrows used in the adult ANT with colourful fish and including an animated feedback to follow the response. With this task, these authors conducted a series of studies intended to trace the developmental course of the attention networks, with children ages 6 to 12 years and adults. Their results show different developmental trajectories for each attention network. For the alerting network, a reliable stable effect was found during middle childhood, with a significant decline of alerting scores from 10 years to adulthood. There was also a reduction of the flanker interference effect between ages 6 and 7 years, and remarkably little difference from 7 years until adulthood. The orienting effect did not change throughout childhood, suggesting a possible maturation of the orienting network before 6 years of age.

Although the study by Rueda et al. (2004) provided information about the developmental trajectory of the attention networks, it did not found evidence of the interactions between attention networks. There are different possible explanations for this result. First, it is possible that interactions among attention networks is a dynamic characteristic that emerge late in development depending upon the maturation of underlying brain structures. This being the case, interactions among networks would be detected later in development or in adulthood. Another possibility is that the characteristics of the task used by Rueda et al. (2004) are not sensitive enough for detecting interactions between networks during childhood.

In the original study of the ANT task, Fan et al. (2002) found interactions between alerting and executive attention and between orienting and executive attention. In order to further explore interactions between alerting and orienting networks, Callejas et al. (2002) conducted a study in which they modified the original ANT task by replacing the visual alerting cue with an auditory warning cue, allowing them to separate the alerting and orienting cue's in order to assess interaction among alerting and orienting network. In this way this modification enables the study of the interaction between alerting and orienting, alerting and executive attention; and orienting and executive attention, providing evidence on how the efficiency of one attention network is modulated by the activation of the others.

Another characteristic of the task used by Rueda et al. (2004) that may tamper its sensitivity was the use of only valid orienting cues. The use of peripheral valid orienting cues allows measuring mostly stimulus-driven orienting processes, which may be subject to earlier development compared to processes entailing disengagement and reorienting of attention (Brodeur & Enns, 1997; Waszak et al., 2010). Thus, not including invalid orienting cues may hinder the detection of more complex processes of disengagement and reorienting of attention and possible developmental changes in the orienting network associated to these types of processes (Schul, Townsend, & Stiles, 2003).

Therefore, in order to address this question we conducted a series of studies using a modified child-friendly version of the ANT task that combined the adaptation introduced by Rueda et al. (2004) with the changes proposed by Callejas et al. (2004) to assess additional processes of development of the attention networks as well as the presence of interactions between them. To increase the orienting effect we included both valid and invalid cues in order to trigger processes of disengagement and reorienting of attention, which would allow detection and evaluation of age-related changes in the orienting network.

In the first experimental series, we expected to replicate previous findings describing different developmental courses for each attention network. Moreover, by increasing the load on orienting by introducing the invalid orienting cue, we expected to find developmental-related changes of the orienting network during childhood. We also expected to characterize the developmental trajectory of attention networks interactions. It has been suggested that attention networks are less differentiated during the first two years of life and becomes more differentiated later on (Posner, Rothbart, Sheese, & Voelker, 2014), thus we expected to find evidence of a protracted developmental trajectory of attention network interactions, specially those interactions that directly influence the efficiency of the executive attention network due to late maturation of the underlying brain structures that supports it.

2.2. Environmental Influences

2.2.1. Is it possible to enhance executive attention efficiency at the cognitive and neural levels by means of process-based training?

Multiple evidence indicates that the development of attention is influenced by both constitutional (e.g. temperament and genes) and environmental (e.g. family socio-economic status, parenting, education, etc.) factors (Posner et al., 2014). This information evinces plasticity of this function and suggests a number of questions related to what are the experiences that would promote the optimal development of attention and self-regulation skills. Several studies have identified a major period of development of executive attention that extends between the end of the first year of life up to late childhood, and is evidenced by efficiency improvements in behavioural measures and maturation of electrophysiological markers (Abundis-Gutiérrez et al., 2014; Rueda, Posner, et al., 2005; Rueda, Fan, et al., 2004; Waszak et al., 2010). In the same way, brain structures that supports executive attention (such as the pre-frontal cortex, PFC) goes trough a protracted developmental which trajectory makes it particularly sensitive to environmental influences (B J Casey, Galvan, & Hare, 2005; B J Casey et al., 2000; Mackey et al., 2013). Based on this evidence, we hypothesized that implementing a cognitive training program during preschool years would enrich children´s environmental stimulation and hence strengthen the development of executive attention processes. To address this experimental question, we conducted a series of studies to be able to identify what are the specific benefits that training produces on behavioural and electrophysiological measures of executive attention. More over, we are interested in assess possible far transfer effects of an attention-training program into intelligence measures and how this effects are associated to the effects produced on conflict monitoring and inhibitory control.

Several studies report benefits of cognitive training in measures related to cognitive control processes and higher cognitive functions, such as intelligence (Bergman et al., 2011; Jaeggi et al., 2008; Jaeggi, Buschkuehl, Jonides, & Shah, 2011b; Rueda et al., 2012; Rueda, Rothbart, et al., 2005). Although in recent years there has been an increase in evidence supporting the benefits of cognitive training, studies that assess the impact on brain structures are needed in order to better understand how changes in brain activation supports associated benefits.

A limited number of studies have evaluated the impact of cognitive training at the level of brain function related to conflict monitoring, measured with electrophysiological data in preschool-aged children (Rueda et al., 2012; Rueda, Rothbart, et al., 2005). Therefore, one of the aims of this experimental series is to further examine the behavioural and neurocognitive effects of an attention-training program in preschool-aged children by studying the influence of training in brain activation related to conflict monitoring and inhibitory control processes. By conducting a randomized control trial of a computer-based intervention to train executive attention skills, we expect to replicate results of previous studies (Rueda et al., 2012; Rueda, Rothbart, et al., 2005) finding near-transfer effects in behavioural measures related to conflict resolution and inhibitory control, and far-transfer effects on fluid intelligence following training. Moreover, using the event related potentials technic (ERPs) and based on previous developmental studies (Abundis-Gutiérrez et al., 2014; Rueda, Rothbart, et al., 2005), we expect a modulation in latency (faster latencies) and amplitude (increase amplitude) of the ERPs related to conflict monitoring (N2/N450) and inhibitory control (P3). In previous studies Rueda et al. (2005, 2012) found that a similar attention training program influences ERP´s related to conflict monitoring by producing similar effects to that of development, indicated by a decrease in latency and an increase in amplitude of the N450 at more posterior sites (Abundis-Gutiérrez et al., 2014; Rueda, Posner, et al., 2004). We expected to replicate these results and to study if a similar pattern is found in ERP´s related to inhibitory control (P3).

2.2.2 Does the combination of process-based training and metacognitive coaching boost the benefits of intervention?

The theory of metacognition indicates that cognitive control it’s related to the interplay of two different components: Metacognitive Control (MC) and Metacognitive Knowledge (MK). Fernandez-Duque et al. (2000) and Shimamura (2008) suggest that MC Is related to cognitive control mechanisms because both mechanisms triggers similar processes and engage similar brain structures. On the other hand, MK it’s considered an important aspect of cognitive control because it allows the creation of a model of one’s own cognition in order to regulate it in an optimal way.

Process-based cognitive training research has focused on developing computerized exercises based on traditional cognitive research tasks known to activate brain regions involved in particular cognitive processes. However, to our knowledge, none of the previous studies have included elements intended to foster metacognitive skills.

On the other hand, educational research provides evidence of the benefits of strategy-based training using interventions that foster MK to improve learning and problem solving skills (Delclos & Harrington, 1991; Ghatala, Levin, Pressley, & Lodico, 1985; Kramarski & Mevarech, 2003). Also, there are studies that examine the benefits of curricula-based interventions designed to improve the emergence of cognitive control processes by integrating elements of social interaction between the student and peers, as well as between student and professors (Diamond & Lee, 2007; Lillard & Else-Quest, 2006; Riggs, Greenberg, Kusché, & Pentz, 2006). Results of these studies are encouraging because they show improvement of several measures of cognitive control, behavioural regulation and learning strategies after strategy-based training programs. Jolles and Crone (2012) suggested that strategy-based interventions improve cognitive control mechanisms by strengthening MK.

To our knowledge no prior study has been conducted that includes both training approaches (i.e. process-based and strategy-based). Therefore, the second aim of our study was to examine the effects of including a metacognitive scaffolding script with the attention-training program previously designed in our lab. The metacognitive scaffolding is intended to provide children with assistance to foster the ability to generate the MK models of task relevant features, which would help them to improve their performance in the training exercises and their awareness of the learning process.

We expect that children who are exposed to training with this type of feedback would strengthened the ability to create MK models, making trainer assistance less necessary and improving their performance in the different exercises by decreasing the number of training trials and in commission errors. Also, it may be possible that the training intervention influence attention processes in a similar way regardless of training strategy, however the influence of the metacognitive training may be detected in measures that are more related to higher order cognitive processes such as reasoning. Therefore, we expected to find evidence of the differential effects of training strategy especially related to far-transfer into intelligence measures, due to the increase engagement of higher cognitive processes that are recruited by the metacognitive scaffolding.

Chapter 3.

Development of Attention Networks and their Interactions in Childhood

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3.1 Abstract

The present study investigated developmental trajectories of alerting, orienting, and executive attention networks and their interactions over childhood. Two cross-sectional experiments were conducted with different samples of 6- to 12-year-old children using modified versions of the attention network task (ANT). In Experiment 1 (N = 106), alerting and orienting cues were independently manipulated, thus allowing examination of interactions between these two networks, as well as between them and the executive attention network. In Experiment 2 (N = 159) additional changes were made to the task in order to foster exogenous orienting cues. Results from both studies consistently revealed separate developmental trajectories for each attention network. Children under 7 years of age exhibited stronger benefits from having an alerting auditory signal prior to the target presentation. Developmental changes in orienting were mostly observed on response accuracy between middle and late childhood, whereas executive attention showed increases in efficiency between 7 years and older ages, and further improvements in late childhood. Of importance, across both experiments, significant interactions between alerting and orienting, as well as between each of these and the executive attention network, were observed. Alerting cues led to speeding shifts of attention and enhancing orienting processes. Also, both alerting and orienting cues modulated the magnitude of the flanker interference effect. These findings inform current theoretical models of human attention and its development, characterizing for the first time the age-related course of attention networks interactions that, present in adults, stem from further refinements over childhood.

3.2 Introduction

Functions of attention include achieving and maintaining a state of alertness, orienting toward and selecting sensory events for preferred processing, and regulating thoughts and responses in a goal-directed effortful mode. This variety of functions has been associated with distinct brain networks (Petersen & Posner, 2012). The *Alerting* network involves the locus coeruleus and areas of the frontal and parietal cortices. The *Orienting* network includes subcortical structures such as the superior culliculus, as well as the superior parietal cortex, temporo-parietal junction, and frontal eye fields. Finally, the *Executive Attention* network comprises the anterior cingulate cortex, lateral and ventral prefrontal cortex, and the basal ganglia. Following this neurocognitive model, Fan and colleagues developed the Attention Network Task (ANT), an experimental task that provides a measure of the efficiency of each of these three networks (Fan, McCandliss, Sommer, Ras & Posner, 2002). In this research, we aim at adapting the ANT to study the development of attention networks during childhood, as well as the possible interactions between networks along this period.

Both the ability to sustain attention (tonic alertness) and the ability to increase response readiness evoked by external cues (phasic alertness) are functions of the *Alerting network*. Developmental studies have shown differences between children and adults in both speed of preparation from alerting cues and maintenance of that preparation (Morrison, 1982). These phasic and tonic aspects of alertness influence reaction times (RTs) when alertness is measured by comparing trials with and without warning cues. Just as adults, young children reduce their RTs to stimuli that are preceded by warning cues (Berger, Jones, Rothbart & Posner

2000). However, despite the fact that children and adults encode warning signals at equivalent rates, children appear to be less efficient (i.e., take longer RTs) processing the warning aspect of the cue (Kraut, 1976; Smothergill & Kraut, 1989).

Regarding mechanisms of the *Orienting network*, there appears to be little differences between children and adults in the ability to shift attention to exogenous cues. However, age-related improvements are documented for the speed of moving attention voluntarily (Akhtar & Enns, 1989; Brodeur & Enns, 1997), and the ability to disengage attention from a location or object (Enns, 1990; Trick & Enns, 1998). Studies involving shifting attention toward peripheral cues that indicate the location of a target stimulus show no changes between six-year-old children and adults (Rueda, McCandliss, Halparin, Gruber & Posner, 2004). In contrast, studies that require re-orientation of attention, as when cues are presented opposite to the location of the subsequent target, have shown that the time to disengage from the location of the cue is reduced with age (Akhtar & Enns, 1989). When the orienting effect is computed by comparing RTs to validly versus invalidly cued targets, a sharp development of orienting is observed until about late childhood (Schul, Townsend & Stiles, 2003; Waszak, Li, & Hommel, 2010). The original ANT triggers orienting by the use of valid exogenous cues, but it does not provide information about the processes of disengagement and re-orienting of attention because invalid orienting cues are not presented.

Executive attention is often studied by tasks that involve conflict between different dimensions of a target stimulus as in the Stroop task, or between the target and distracting information, as in the Flanker task (Posner, Rueda & Kanske, 2007). Developmental studies about executive control of attention have suggested that this network strongly develops during early childhood (Rueda, Posner & Rothbart, 2005; Rueda, 2014). Specifically, children typically progress from an almost complete inability to carry out conflict tasks to a relatively good performance on these tasks between ages 2 and 7 years (Gerardi-Caulton, 2000; Rueda et. al., 2004). A study using a flanker task with arrows pointing left or right, showed that children up to age 7-9 years experience greater interference than adults from incongruent flanking arrows, particularly at the response selection level (Ridderinkhof & Van Der Molen, 1995). Additional data with other tasks involving executive attention indicate that this function shows a protracted development during childhood (Kray, Eber, & Linderberger, 2004), and depending on the demands of executive processes (e.g., working memory) may extend to adolescence and early adulthood (Davidson, Amso, Cruess, & Diamond, 2006; Diamond, 2013). A recent study using a color version of the flanker task, reported a steady development of conflict processing during childhood and adolescence and up to adulthood, as well as a decline in the elderly (Waszak, et al., 2010).

Most of the prior studies that have examined the development of attention networks have been carried out with tasks that measure each network independently. One advantage of the ANT is that it provides a measure of the three attention networks within the same experimental procedure, thus allowing examination of interactions between them. Rueda et al. (2004) developed a child-friendly version of the ANT, wherein the arrows of the original ANT were replaced with colorful fish. The Child ANT was used to conduct a series of studies with children aged 6 to 10 years and young adults intended to trace the developmental course of the attention networks (Rueda et al., 2004). In that study, no changes in the orienting effect with age were observed. However, results showed stability of the alerting effect during middle childhood, but a significant reduction of the alerting score between 10-year-olds and adults. Likewise, a decrease in the size of the flanker interference effect was found between ages 6 and 7, and little or no difference from 7 years up to adulthood.

3.2.1 Interactions between Attention Networks

Although the attention networks are associated with distinct brain circuits, there is evidence suggesting that they are not functionally independent (Callejas, Lupiañez, & Tudela, 2004). Fan et al.'s (2002) study showed a significant interaction between cue and flanker conditions, showing increased flanker interference effects under cues conveying alertness. To further study interactions between the attention networks, Callejas et al. (2004) developed a modified version of the ANT. In their task, different trial events were used to manipulate alerting (auditory tone) and orienting (valid and invalid visual cues). Their results revealed significant interactions between alerting and orienting, as well as between each of these networks and the executive attention network. The alerting x orienting interaction indicated that the orienting effect was larger in conditions with alerting cues. Evidence from subsequent studies suggests that alerting could both speed shifts of attention (Callejas, Lupiáñez, Funes, & Tudela, 2005) and enhance selection with cue-target intervals of up to 500 ms (Fuentes & Campoy, 2008). Additionally, both alerting and orienting cues modulated the size of the flanker interference effect. Alerting cues lead to larger flanker interference, an effect that has been interpreted as indicative of an inhibitory relation between the alerting and executive attention networks. The idea is that fast and automatic responses are prioritized over controlled behavior after preparation cues are presented (Posner, 1994). However, data from a recent study with adults suggest that alerting may also broadens the attentional focus leading to increased processing of distracting information in the flanker task (Weinbach & Henik, 2012). On the other hand, larger interference effect in trials with invalid orienting cues compared to valid or no-cue trials has also been reported (Callejas et al., 2005). This indicates that correct orientation of attention prior to the occurrence of the target may help focusing attention and filtering out distracting stimulation, whereas the opposite occurs in trials with invalid cues, allowing more interference from distracters.

To our knowledge, no prior study has examined interactions among the attention networks in detail during childhood. The present study intends to fill that lack. By assessing interactions between attention functions we might help explaining inconsistent data about the developmental course of each function. Given that alerting and orienting functions appear to have an earlier developmental course to that of executive attention, we expected to observe modulation of these networks over executive control from early childhood. Also, we expected that this modulatory effect would have greater impact when less efficient forms of executive control are likely to be observed, as in early compared to middle or late childhood. At early ages, the executive system may largely benefit from conditions that facilitate filtering out irrelevant information. With this purpose, we modified the child ANT according to changes introduced by Callejas et al. (2004) and ran two studies with 6- to 12-year-old children.

3.3 Experiment 1

Method

3.3.1 Participants

Participants in Experiment 1 were recruited from local schools in an urban area of southern Spain. Children (N=106) with ages ranging between 6 and 12 years participated in the study. Informed consent was obtained from caregivers prior to participation. Children with normal or corrected-to-normal vision and no history of developmental disorders where included in the study. Descriptive statistics of the sample are presented in the upper part of table 3.1. There was no significant differences in total intelligence score, as measured with the Kaufman Brief Intelligence Test (K-BIT), between age groups (F(1,97) = 1.47, p > .10).

	Experiment 1			**Experiment 2**		
Age Group	**n (males)**	**Age in months**	**IQ score**	**n (males)**	**Age in months**	**IQ score**
6 yr.	11 (4)	80 (2.9)	108 (9.7)	13 (7)	80 (1.8)	113 (6.8)
7 yr.	12 (8)	90 (3.6)	108 (6.9)	22 (12)	89 (3.0)	110 (10.9)
8 yr.	28 (11)	97 (2.8)	108 (11.3)	28 (19)	101 (3.7)	106 (13.1)
9 yr.	17 (9)	112 (3.3)	103 (9.2)	21 (12)	112 (2,7)	106 (10.2)
10 yr.	13 (5)	127 (3.4)	100 (10.2)	22 (13)	124 (3.4)	105 (8.9)
11 yr.	14 (9)	136 (3.2)	104 (7.8)	26 (14)	137 (3.0)	108 (8.1)
12 yr.	11 (5)	149 (5.0)	105 (15.0)	18 (9)	146 (2.1)	109 (10.8)

Table 3.1. Descriptive data of participants in Experiment 1 and 2. Mean (SD) of age in months and composite IQ are provided for each age group.

3.3.2 Task and stimuli

A schematic representation of the experimental task is presented in figure 3.1. Each trial started with either an alerting cue consisting on a 50 ms–long 2000 Hz tone presented in 50% of trials or a blank frame for the same duration with no tone. Four hundred milliseconds after the alerting cue, a visual orienting cue (i.e., an asterisk) was presented on two thirds of the trials for 100 ms. No cue was presented in the remaining one third of trials. The orienting cue was presented about 1° of visual angle above fixation on half of the trials and about 1° below it on the remaining half. Also, on half of the trials the cue was presented in the same location as the upcoming target (i.e., valid cue), whereas in the other half it was presented in the opposite location (i.e., invalid cue). Fifty milliseconds after the orienting cue, the target array was presented either above (in half of the trials) or below fixation. The target array consisted of a row of five yellow fish, which remained on the screen until a response was made or up to 2500 ms. In half of the trials, the fish in the middle pointed to the same direction as those on the sides (congruent trials), whereas it pointed to the opposite direction as the flanking fish (incongruent trials) in the remaining half. Each fish subtended 1.6° of visual angle and the contours of adjacent fish were separated by 0.21° viewed at an approximated distance of 50 cm. An animated feedback lasting 1 second was presented after completion of the target frame. The feedback consisted of the middle fish blowing bubbles and moving the tail together with the sound "*woohoo*!" for correct responses, or a single tone and no animation for incorrect or omitted responses. A fixation cross displayed at the center of the screen was presented throughout the trial, and remained on the screen during the inter-trial interval, which had a random duration between 500 and 4200 ms. After completion of each experimental block, a between-block feedback was presented, providing information on both accuracy and speed of response. The presentation of the stimuli and collection of responses was controlled with E-prime 2 (Psychology Software Tools, Inc; http://www.pstnet.com/eprime.cfm).

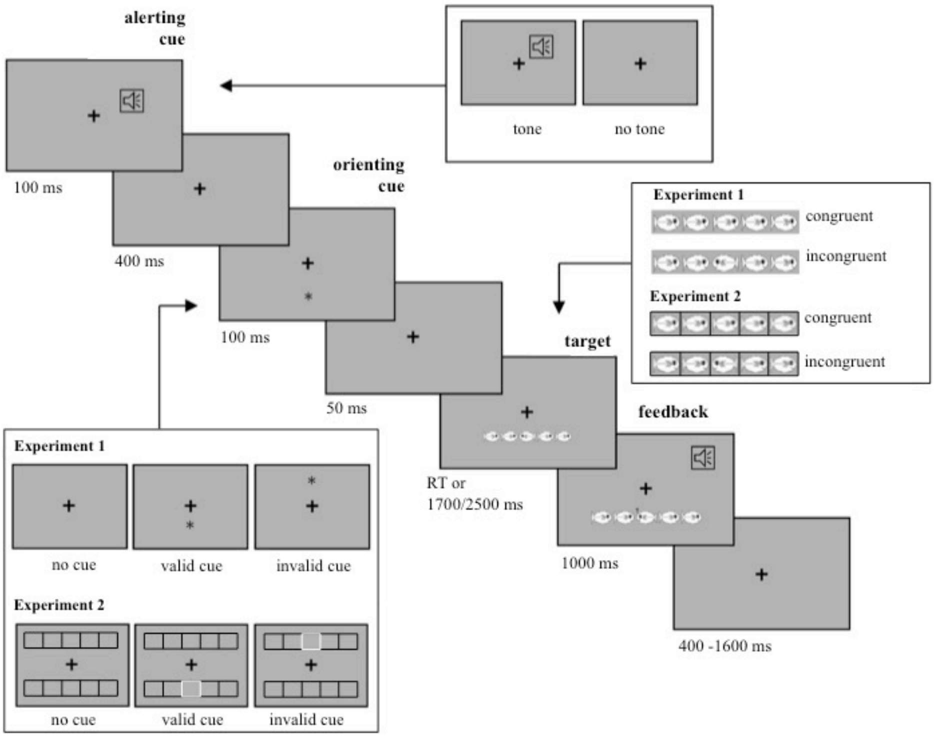

Figure 3.1. Schema of the experimental tasks used in the study. In Experiment 2 the location of stimuli was signaled by squares that were present throughout the task.

3.3.3 Procedure

The experimental sessions were conducted in small groups of 6 children at once in a quiet classroom at school. Children wore headphones while performing the task. Each session consisted of one practice block of 24 trials and 6 experimental blocks of 48 trials each, a total of 288 experimental trials, 24 trials of each of the 12 experimental conditions: 2 (Alerting: tone vs. no-tone), x 3 (Orienting: valid-cue, invalid-cue, no-cue) x 2 (Executive Attention: congruent vs. incongruent). Conditions were randomly chosen in each trial. Accuracy and speed of responses were registered in each trial.

Participants were told that a group of five fish would appear on the screen, either above or below the fixation cross. They were instructed to pay attention to the fish in the center of the array and feed it by pressing the button of the mouse that matched the direction the fish was pointing to. An instruction block consisting on four trials (two congruent and two incongruent) where conducted to explain the task. Finally, participants were encouraged to maintain fixation at the central cross throughout the task and to respond as quickly and accurately as possible.

3.3.4 Results

All participants had a percentage of errors that did not exceed 2 SD from the mean of its particular age group and therefore none was excluded from the study. The percentage of trials with errors of omission was low (*M* = 1.51, SD = 1.56) and did not differ (F<1) among age groups, therefore accuracy analysis only take into consideration the percentage of commission errors.

3.3.4.1 Attention networks scores

Scores for each attention network were computed using both RTs and percentage of errors. The *Alerting score* was computed by subtracting median RTs or percentage of errors in trials with tone from trials without a tone. The *Orienting score* was calculated by subtracting the dependent measures on trials with the valid cue from those with the invalid cue. Finally, the *Executive Attention score* was the result of subtracting median RTs or percentage of errors in trials with congruent flankers from trials with incongruent flankers. The left side of table 3.2 presents the attention network scores obtained by each age group in Experiment 1.

	Experiment 1						Experiment 2					
	Alerting Score		**Orienting score**		**Executive attention score**		**Alerting score**		**Orienting score**		**Executive attention score**	
Age Group	**RT**	**% Errors**	**RT**	**% Errors**	**RT**	**% Errors**	**RT**	**% Errors**	**RT**	**% Errors**	**RT**	**% Errors**
6 yr.	30 (19.7)	0.6 (3.8)	85 (33.5)	9.3 (11.5)	70 (33.2)	5.5 (9.5)	28 (31.0)	0.6 (5.0)	95 (29.2)	6.2 (4.5)	51 (25.7)	6.4 (6.1)
7 yr.	32 (13.2)	1.7 (4.9)	64 (27.3)	6.0 (6.3)	78 (28.3)	7.7 (6.5)	31 (19.6)	2.2 (4.4)	87 (27.3)	5.1 (5.4)	59 (32.3)	6.9 (5.1)
8 yr.	17 (18.3)	-0.4 (2.8)	77 (23.9)	3.2 (3.5)	65 (28.2)	3.6 (4.6)	22 (23.0)	1.7 (3.9)	88 (29.6)	3.5 (4.3)	56 (21.5)	4.2 (3.1)
9 yr.	10 (18.9)	0.2 (2.1)	72 (23.1)	4.3 (4.5)	54 (22.4)	5.3 (4.6)	24 (18.5)	1.7 (2.8)	90 (30.5)	2.5 (3.4)	49 (21.1)	4.3 (3.2)
10 yr.	14 (17.7)	0.5 (1.9)	58 (16.8)	3.6 (8.8)	60 (23.9)	6.2 (10.9)	16 (16.0)	0.7 (3.6)	81 (19.2)	1.6 (3.3)	39 (23.4)	3.7 (2.5)
11 yr.	12 (15.1)	-0.02 (1.5)	79 (23.6)	2.1 (3.0)	58 (10.4)	3.9 (2.7)	16 (16.8)	0.8 (2.3)	87 (21.5)	1.6 (2.4)	41 (22.5)	2.0 (2.1)
12 yr.	8 (19.1)	0.06 (2.1)	64 (25.9)	2.2 (2.4)	42 (16.0)	2.8 (2.6)	10 (19.2)	0.6 (1.2)	82 (16.8)	1.9 (2.2)	45 (19.0)	2.0 (1.6)

Table 3.2. Attention networks scores with RT (in ms) and response accuracy (percentage of errors) per age group obtained in Experiment 1 and Experiment 2. SDs between brackets. RT, reaction times.

Group differences on these scores were analyzed by means of one-way analyses of variance (ANOVAs) with Age as the between-subjects factor. The main effect of Age was significant for the Alerting score (F(6,99) = 3.52; p< .01) and the Executive Attention score (F(6,99) = 2.61, p < .05), but did not reach statistical significance for the Orienting score (F(6,99) = 1.94, p = .08). To further explore age differences in the network scores, we first performed Fisher LSD tests in order to determine where differences between groups emerged. Then, age groups that did not differ from each other were clustered to carry out planned comparisons. For ease of communication, only data from planned comparisons are reported. Those analyses revealed a significant reduction in the Alerting score between 6-7 and 8-12 years (F(1,99) = 19.21, *p* < .01). As for the Executive Attention score, 6-8 differed significantly from 9-12 years (F(1,99) = 11.64; p < .001. Also, the oldest group differed significantly from 6 to 8 years (F(1,99) = 11.9; p < .001), but only marginally from 9 to 11 years (F(1,99) = 3.40; p = .07). Regarding the Orienting network score, we ran planned contrasts to assess differences between the youngest children and the rest of the groups. Comparisons revealed significant differences for the contrasts 6 vs. 7 (F(1,99) = 3.95; p < .05), 6 vs. 10 (F(1,99) = 7.02; p < .01), and 6 vs. 12 (F(1,99) = 3.83; p = .05) years. Regarding analyses with errors, the main effect of Age was significant only for the Orienting score (F(6,99) = 2,16; p< .05). Subsequent planned comparisons revealed a significant reduction in the Orienting score between 6-7 and 8-12 years (F(1,99) = 57.08, p < .001). There was no significant effect of age for both Alerting and Executive Attention scores (Fs < 1).

3.3.4.2 Interactions among attention networks

Data summarizing interactions among networks in this experiment are presented in the leftmost part of table 3.3. To examine the interaction between Alerting and Orienting networks, orienting scores were computed separately for each alerting condition and entered in a 2 (Alerting) x 7 (Age) Mixed-Model ANOVA. Likewise, executive scores were computed separately for each of the alerting (tone vs. no-tone) and orienting (valid vs. invalid) conditions to examine Alerting x Executive and Orienting x Executive interactions and their possible modulation by Age. Results revealed a significant modulation of orienting conditions over executive scores with both RTs (F(1,99) = 94.61, p < .001) and percentage of errors (F(1,99) = 94.61, p < .001), but no modulation of alerting over neither orienting nor executive attention scores (all Fs < 1). Moreover, Age qualified none of these effects.

		Experiment 1		**Experiment 2**	
		RT	**% Err**	**RT**	**% Err**
a) AL x OR		*n.s.*	*n.s.*	*	*n.s.*
	No-Tone	70 (31)	3.0 (4.9)	83 (35)	2.8 (4.6)
	Tone	72 (29)	3.5 (5.5)	91 (31)	2.5 (4.2)
b) AL x EX		*n.s.*	*n.s.*	*n.s.*	***
	No-Tone	43 (41)	3.3 (6.8)	39 (46)	**4.4 (6.8)**
	Tone	48 (47)	4.1 (6.7)	41 (41)	**2.0 (5.9)**
c) OR x EX		***	***	***	***
	Valid	44 (31)	1.9 (4.6)	32 (25)	2.3 (3.5)
	Invalid	89 (35)	6.3 (7.2)	75 (34)	5.1 (5.9)

Table 3.3. Interactions among networks. Orienting scores with both RT and percentage of errors presented in function of alerting conditions (a). Executive scores with RT and percentage of errors particular alerting (b) and orienting (c) conditions. Data in bold indicate that the interaction is qualifi by Age (see Figure 2). Statistics effects: n.s. non significant (p>.1); *p<.05; ***p<.001

3.3.5 Discussion

As predicted, results of Experiment 1 revealed separate developmental trajectories for each attention network, which was evinced by changes in the network scores as a function of age. With RTs, the alerting score was significantly reduced after age 7, with no further changes from age 8 to 12 years. With errors, the Alerting score is expected to be negative, as it has been largely documented in adults, who tend to commit more errors when a warning cue is provided compared to when no warning cues precede the target (Posner, 1978). In the age range here studied, the alerting score was close to zero for children 8 to 12 years, but greater than zero for the youngest children (i.e., 6-7 years). Scores greater than zero indicate that more errors are committed in the no-tone than the tone condition. If young children have poorer tonic alerting levels, as RT data suggest, having a warning cue prior to the target is likely to produce beneficial rather than harmful effects on response accuracy because the cue can help on regaining attention on the task.

The effect of age on the Orienting network score was clearer-cut for errors than for RTs. Nevertheless, in both measures the youngest group showed larger scores than older children, meaning that their responses were comparatively slower and less accurate when having to reorient attention to the location of the target. Many studies that have looked at exogenous orienting effects with children and adults have used orienting cues consisting of luminance changes of a frame that defines the area in which the target stimulus would be located (Schul, Townsend & Stiles, 2003; Waszak et al., 2010; Ortega, López, Carrasco, Anllo-Vento & Aboitiz, 2013), as in the original orienting paradigm proposed by Posner (1980). The nature of the cues used in the current study may account for the differences observed in our study and those finding significant reductions in the RT orienting effect along childhood. This hypothesis will be tested in the next experiment.

Regarding the Executive Attention score, differences were observed between young children, aged 6 to 8 years, and 9 to 12 years, and a further decrease trend for the oldest group. In the study by Rueda et al. (2004) using the original child ANT, no further decreases in the executive score were observed after age 7, however the inclusion of invalid orienting cues in the current study is likely to have made the task more difficult, leading to steeper developmental changes in this network. In fact, a significant Orienting x Executive Attention interaction was observed in our study, indicating that the executive score was larger under invalid orienting conditions, as will be discussed below.

Regarding interactions among networks, we only found a significant Orienting x Executive Attention interaction with both RTs and errors. This interaction was due to a reduction of the flanker interference effect under valid orienting cues compared to invalid cues (see Table 3). Children of all ages showed equivalent rates of benefit from valid cues over focalization of attention and suppression of irrelevant stimuli. This can be related to the fact that we did not find a clear effect of age on the RT orienting score in our study. To test whether the nature of the cue was responsible for the lack of age differences in the orienting effect, we ran a second experiment in which frames were used to enclose the location of stimuli. Altering the luminance of the frames would serve to foster exogenous orienting by cues.

3.4 Experiment 2

3.4. Method

3.4.1. Participants

A total of 159 children ranging between 6 and 12 years of age, who met the same inclusion criteria as in Experiment 1 and whose parents/tutors provided informed consent, participated in Experiment 2. There was no significant differences in total intelligence score between age groups (F(1,149) = 1.59, p > .10). Children with more than 2 standard deviations (SD) above the mean percentage of errors of their age group (n=9) were discarded from the analyses. Descriptive data of the final sample are presented in the rightmost part of Table 1.

3.4.2. Task, stimuli, and procedure

In Experiment 2, the location of stimuli was marked with squares that were presented throughout the entire task. The orienting cue consisted on highlighting the position of the square in the middle, either above or below the fixation point. The square could be highlighted either in the same location as the target (valid cue), or in the opposite location (invalid cue). In the no-cue condition the square was not highlighted (see figure 3.1). The remaining stimuli and timing parameters were identical to the ones used in Experiment 1 as it was the procedure followed to administer the task.

3.4.3. Results

The overall percentage of omission errors was 2.07 (SD = 2.44), and no differences were observed between age groups (F < 1) in this measure.

3.4.3.1. Attention networks scores

The rightmost part of Table 2 presents the scores for each attention network and age group with both RT and errors. One-way ANOVAs with RTs showed a statistically significant main effect of Age for the Alerting (F(6,143) = 2.64, p < .05) and Executive Attention (F(6,143) = 2.21, p < .05) scores, but not for Orienting scores (F < 1). The developmental course of alerting was assessed with planned comparisons, which revealed significant differences between 6-9 and 10-12 years (F(1,143) = 12.79; p < .001), given that alerting scores of the 8-9 years differed significantly from those of the 10-12 years (F(1, 143) = 5.16, p < .05) but not from 6-7 years (F(1, 143) = 2.22, p = .14). Regarding the Executive Attention score, a statistically significant reduction was observed between 6-9 and 10-12 years (F(1,143) = 9.27, p < .01).

Regarding errors, we found a statistically significant effect of Age for the Orienting (F(6,143) = 4.17, p < .001) and Executive Attention (F(6,143) = 5.68, p < .001) scores. No effect of Age was obtained for the Alerting score (F<1). The Orienting score followed a linear reduction between age 6 and 10, and no changes from age 10 to 12 (F(1,143) = 22.83, p < .001). On the other hand, the curve of the Executive Attention score showed two inflection points, one between 6-7 and 8-10 years (F(1, 143) = 11.54, p < 001) and a second one between 8-10 and 11-12 years (F(1, 143) = 8.72, p < .01).

3.4.3.2 Interactions among networks

The rightmost part of table 3.2 presents data summarizing interactions among networks in Experiment 2. Analyses of interactions were conducted following the same procedure as in Experiment 1. Alerting conditions modulated the size of orienting scores as calculated with RTs (F(1,142) = 4.48, p< .05). Likewise, orienting conditions modulated the size of executive scores as calculated with both RTs (F(1,142) = 192.04, p < .001) and errors (F(1,142) = 27.69, p < .001). Finally, alerting conditions modulated executive scores only when calculated with errors (F(1,142) = 18.69, p < .001). However, this last effect was qualified by Age (F(6,142) = 5.16, p < .001). The Alerting x Age interaction with executive scores as dependent variable is presented in Figure 2. Post-hoc contrasts were performed using Bonferroni adjusted alpha levels. Results revealed that the flanker interference effect was significantly larger in the no-tone condition compared with the tone condition for 6- (F(1,142) = 19.37, p < .001) and 7-year-old children (F(1,142) = 21.08, p < .001), whereas it did not reach statistical significance for 8- (F(1,142) = 2.25, p = .14), 9- (F < 1), 10- (F(1,142) = 2.10, p = .15), 11- (F < 1) and 12-year-old (F(1,142) = 1.14, p = .29) children.

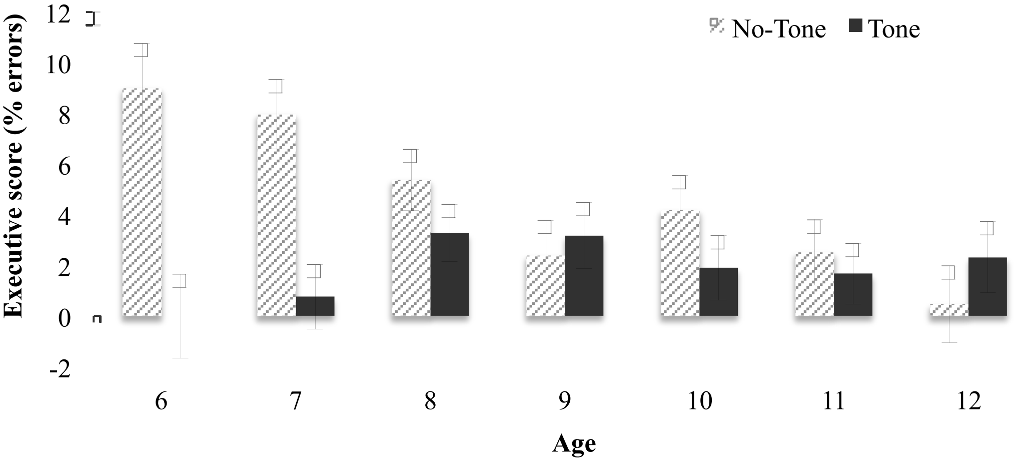

Figure 3.2. Graph depicting executive attention scores in function of alerting conditions and age group obtained in Experiment 2.

3.5 Comparison of Experiments 1 and 2

To test for effects due to changes introduced in Experiment 2 with respect to Experiment 1, and to examine whether the developmental trajectories of the attention networks were influenced by those changes, we carried out a series of factorial ANOVAs in which Experiment (1, 2) and Age (6, 7, 8, 9, 10, 11, and 12 years) were included as between-participants factors and each of the network scores as dependent measures. In these ANOVAs, the Experiment x Age interaction was not statistically significant for any network score either using RT or accuracy measures (all Fs < 1). However, we found a significant main effect of Experiment in RT analyses for both the Orienting (F(1,242) = 21.7, p < .001) and the Executive Attention (F(1,242) = 14.7, p<.001) scores. This result suggests that the experimental changes introduced in Experiment 2 produced larger Orienting effects (72 ms in Exp1 *vs* 87 ms in Exp2) and reduced Executive Attention scores (61 ms in Exp1 *vs* 49 ms in Exp2). The effect of Age was significant with Alerting (F(6,242) = 5.22, p < .001) and Executive Attention

(F(6,242)=3.99, p<.001) scores, but only marginal F(6,242) = 1.99, p = .07) with Orienting scores. Age changes in alerting were found between 6-7 years and the older groups (F(1,242) = 26.1, p < .001). Also, a linear reduction between 8 and 12 years of age reached statistical significance (F(1,242) = 5.94, p < .05). Regarding Executive Attention, the developmental curve showed an inflection point between 8 and 9 years (significant 6-8 vs. 9-12 groups comparison, F(1,242) = 20.11, p < .001).

Analyses using accuracy scores revealed marginal main effects of Experiment with Alerting (F(1,242) = 3.61, p = .06) and Orienting scores (F(1,242) = 3.47, p = .06). These effects were due to a trend for higher Alerting accuracy scores in Experiment 2 (*M* = 1.2, SD = 0.27) compared with Experiment 1 (*M* = 0.4, SD = 0.32), as well as lower Orienting accuracy scores in Experiment 2 (*M* = 3.2, SD = 0.40) relative to Experiment 1 (*M* = 4.4, SD = 0.48). The effect of Age was significant with Orienting (F(6,242) = 5.36, p < .001) and Executive Attention scores (F(6,242) = 3.72, p < .01), and not with Alerting scores (F < 1). Orienting scores were significantly larger for 6-7 years than the rest of the age groups (F(1,242) = 28.75, p < .001). Regarding Executive Attention, differences were observed between 6-7 and 8-10 years (F(1, 242) = 6.77, p < .01), and also between the last group and 11-12 years (F(1, 242) = 5.97, p < .05).

Figure 3.3 presents the developmental trajectories of each attention network by plotting scores for both RT (fig. 3.3a) and response accuracy (fig. 3.3b) as a function of age with data from Experiment 1 and 2 combined.

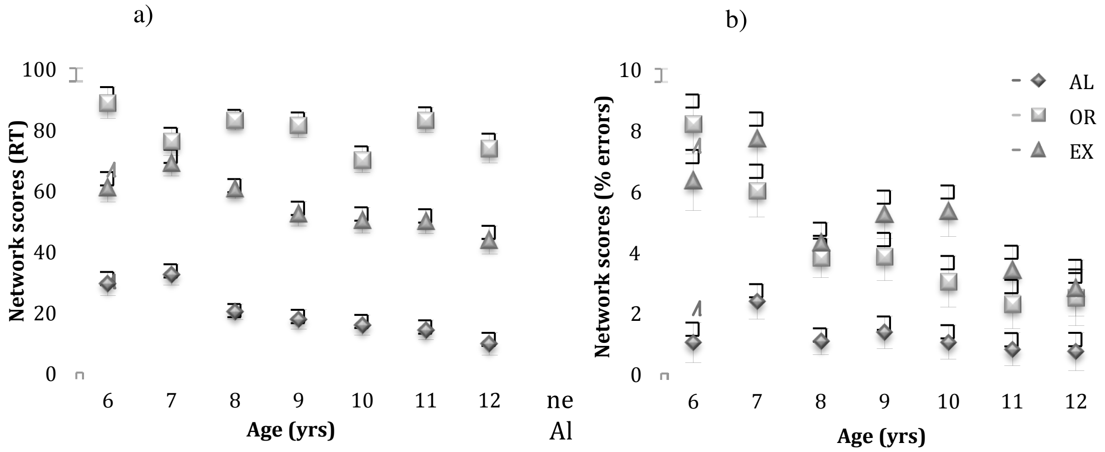

Figure 3.3 Developmental course of attention networks with RT (a) and error percentage (b). Data from Experiment 1 and 2 are combined. AL, Alerting; OR, Orienting; EX, Executive Attention.

3.5.1 Discussion

Framing the location of stimuli causes a general reduction in Executive Attention scores by facilitating focalization of attention on the central target, hence diminishing the processing of distracting flankers. Additionally, orienting cues utilized in Experiment 2 appear to produce stronger attention capture than those used in Experiment 1, leading to greater difficulties to disengage attention from the cued location. This is indicated by the fact that RT increases in the orienting score in Experiment 2 with respect to Experiment 1 were only observed in the invalid cue condition (from 653 in Exp1 to 680 ms in Exp2, $F(1, 242) = 13.14$, $p < .001$, compared to a non-significant increase from 580 in Exp1 to 593 ms in Exp2 for valid-cue trials). On the other hand, variations introduced to the task did not affect alerting scores. This was expected given that the alerting cue used in the current experiment was identical to the one utilized in the previous study. More interesting is the fact that changes in the experimental conditions did not alter the developmental course of the attention networks, as indicated by the lack of Experiment x Age interactions.

The interactions among the networks showed a similar pattern in both experiments (see Table 3). However, in Experiment 2 alerting conditions modulated the size of executive scores as calculated with errors, and this modulation changed with Age. Young children showed larger executive scores when no alerting cues were presented, whereas from 8 years up children showed equivalent executive scores with and without alerting tone (see Figure 2). Only 12 year-old children showed the pattern usually found in adults (i.e., larger interference scores under higher alerting conditions) although the difference did not reach statistical significance. We believe this result can be explained by young children's poorer level of sustained attention or tonic alertness in the absence of warning cues. This being the case, warning cues should help rather than hinder task performance in young children.

3.6 General Discussion

The studies presented here had two main goals. First, we sought to further understand the development of attention networks over childhood. Second, based on the interactions among the attention networks that have been documented in adults (Callejas et al., 2005; Weinbach & Henik, 2012), we wanted to examine whether those interactions were present, and/or modulated by age, during childhood. According to these goals, a number of modifications were introduced to the original child-version of the ANT (Rueda et al., 2004). We separated alerting and orienting events, which allowed for the independent manipulation of these two networks. We also introduced invalid orienting cues, which provided a measure of orienting that was influenced by processes of disengagement and re-orienting of attention from wrongly cued locations. Additionally, the display of the task was changed in the second experiment, in which the location of stimuli, both target and distracters, was marked by frames, and orienting cues were conveyed by briefly changing the brightness of the central frame.

3.6.1 Development of the attention networks

The developmental curve of the alerting network in RT data showed a significant decline between the younger (i.e., 6 and 7 years) and the older groups, and a progressive reduction from 8 to 12 years of age. Larger alerting scores indicate that young children benefit more than older children from having a warning auditory signal prior to the presentation of the target. This is due to their slower responses when no auditory tone is presented, which is indicative of young children's greater difficulties in maintaining an optimal level of tonic alertness in absence of warning cues. On the other hand, judging by the lack of age effects on the alerting scores calculated with percentage of errors (see Figure 3b), it could be thought that alerting conditions do not affect overall response accuracy across ages. However, the Alerting x Executive Attention x Age interaction depicted in Figure 2 indicates that while alerting signals help conflict resolution in young children, they have a harm effect on conflict resolution in the older groups. These effects of alerting over executive attention suggest that, compared to older children, young children show reduced sustained (tonic) alertness, a requisite for the optimal functioning of the attention system.

Young children showed larger orienting scores than the rest of the age groups (see Figure 3b). This indicates that invalid cues compromise response accuracy to a larger extent in children below age 8. Also, 6-year-old children showed larger orienting scores in RTs than children with 8 and 12 years, suggesting a developmental improvement in orienting and re-allocation of attention during the age range studied here. Previous studies have reported a lack of age effects in orienting to valid cues when comparing children beyond age 5 and adults (Enns & Brodeur, 1989; Wainwright & Bryson, 2002). In fact, a prior developmental study using the original child ANT, in which only valid orienting cues were used, showed no age-related changes in the orienting score between children of 6 and 10 years of age (Rueda et al., 2004). Modifying the ANT to include invalid orienting cues, and calculating the score by subtracting valid-cue form invalid-cue trials, provides a measure of orientation that mainly grasp processes related to disengagement and re-allocation of attention. In consonance with our data, significant improvements in performance between 8 and 11 years of age has been reported when children have to disengage attention from the attended channel and reallocate it to the other channel in the auditory modality (Pearson & Lane, 1991), as well as the visual modality (Waszak et al., 2010). Mounting evidence indicates that switching attention is associated with activation of cortical structures of the parietal and frontal lobes (e.g., Corbetta & Shulman, 2002). Invalid exogenous cues have been shown to modulate the amplitude of the P300, an event-related potential observed over temporo-parietal sites that is associated with activation of the temporo-parietal junction (TPJ; Bledowski, Prvulovic, Goebel, Zanella, & Linden, 2004), a structure within the orienting network. Activation of the TPJ appears to reflect a relatively slow operation of readjustment of attention needed when the expectation of a target at the cued location is broken. Compared to adults, children below 8 years of age appear to have a larger modulation of the P300 in response to exogenous invalid cues (Abundis-Gutiérrez, Checa, Castellanos, & Rueda, 2014). Thus, our results are consistent with the extant empirical evidence and suggest that the function of the orienting network continues developing from middle to late childhood.

Executive attention scores showed a progressive decline with age, which was more pronounced with response accuracy (see Fig. 3). With RTs, the developmental curve showed an inflection point between 8 and 9 years of age, whereas with accuracy, differences were observed between 6-7 and 8-10 years, and also between the last group and 11 to 12 years. Overall, these data demonstrate that executive attention improves significantly between middle and late childhood. With a simpler version of the ANT, as when only valid orienting cues are used (Rueda et al., 2004), executive attention was shown to have an earlier maturational course. Inclusion of invalid orienting cues in one third of the trials caused increased interference from flankers, as indicated by the significant Orienting x Executive Attention interaction obtained in both experiments (see Table 3). This change in the task led to a more protracted development of conflict resolution. This result is consistent with evidence from previous developmental studies showing age-related reductions of flanker interference beyond age 7 (Fjell et al., 2012; Waszack, et al., 2010). In these studies, different versions of the flanker task (e.g., with arrows or geometrical shapes) were used, which could tentatively be more challenging than the fish version utilized in the Child ANT.

Much evidence has pointed to the dorsal part of the ACC, and more generally the medial frontal cortex, as the main neural node of the brain network involved in cognitive control (Bush, Luu, & Posner, 2000; Posner, Rothbart, Sheese, & Tang, 2007; Ridderinkhof, Ullsperger, Crone, & Nieuwenhuis, 2004). Recently, it has been shown that the extension of the surface area of the medial frontal cortex predicts children's performance of incongruent trials in the flanker task (Fjell et al., 2012). Other structures of the control network are relatively distant areas of the superior and inferior parietal lobe and the precuneus, as well as areas of the inferior frontal cortex and the anterior insula (Dosenbach, Fair, Cohen, Schlaggar, & Petersen, 2008). Developmental studies conducted with neuroimaging techniques suggest that the fronto-parietal network involved in cognitive control shows increased functional connectivity over development, particularly between 7-9 years of age and early adolescence (Fair, et al. 2007). This is consistent with immature fronto-parietal activation shown by 8- to 12-year-old children compared with adults while performing the ANT (Konrad et al., 2005). Immature fronto-parietal connectivity and activation may be causing a delay in stimulus-to-response translation processes in young children with respect to older children and adults when incongruent information is present in the display (Ridderinkhof, et al., 1997). This would explain why young children exhibit greater difficulty to reduce interference, as it was observed in the present experiments and other studies using conflict tasks (Davidson et al., 2006).

3.6.2 Interactions between the attention networks

The second goal of the present research was to examine whether the interactions between the attention networks observed in adults are present in children, and whether they change with age during childhood. A larger orienting effect under conditions of higher alertness was observed in Experiment 2 (see Table 3). This result has been previously reported in adults and interpreted as either and effect of speeding up orientation (Callejas et al., 2005) or enhancing attentional selection (Fuentes & Campoy, 2008) with increased alertness. Our results are consistent with the idea of alerting improving the function of orienting, either by orienting faster, increasing the selection of the target, or both. Moreover, the fact that no second-order interaction with age was observed suggests that either the influence of alerting over orienting is an essential characteristic of the attention system or that the influence of one network over the other develops earlier than the age range tested in our study.

Regarding the influence of the Alerting and Orienting networks over the efficiency of Executive Attention, two main results were obtained. First, we observed a robust facilitatory effect of orienting over conflict processing, as shown by the reduced flanker effect (i.e., the Executive Attention score) for both RTs and percentage of errors after a valid orienting cue was provided (see Table 3). Data show that invalid orienting cues lead to much larger RTs and higher error rates in trials with incongruent flankers. Exogenous orienting cues trigger automatic shifts of attention toward the location of the cue (Posner, 1980). Focalization of attention ahead of time helps on filtering out distracting information when the subsequent target appears in that same location. On the contrary, when the target appears in a different location, a potentially effortful process of disengagement and reorienting of attention has to be voluntarily initiated, which leaves less resources available to suppress distracting stimulation.

The second influence on executive attention efficiency was that of alertness. High alerting states are known to cause poorer performance in detection as well as conflict resolution tasks (Posner, 1978; Aston-Jones, Rajkowski, & Cohen, 1999). This usually results in larger flanker effects following warning cues compared to when no cue is presented. As shown in Table 3, in none of our experiments the alerting cues modulated the size of the flanker effect with RT. This lack of interaction indicates that warning cues do not reduce the efficiency of conflict resolution in children. However, in experiment 2 children showed larger interference effect in response accuracy when no warning cues were presented compared to trials with auditory tones. More interestingly, this interaction was modified by age (see Figure 2), indicating that while young children (i.e., aged 6 to 8 years) showed larger interference effects in the absence of warning cues, older children showed either equivalent interference effects in the two alerting conditions or the adult-like pattern showed by the oldest group. This result might be related to young children's difficulties in sustaining attention in absence of alerting cues. It is well documented that that the relationship between alertness and performance is best described by an inverted U-shaped curve, a phenomenon largely known as the Yerkes-Dodson law (Yerkes & Dodson, 1908). Some authors have suggested that the alertness level of the organism closely follows the tonic level of activation of the locus coeruleus (LC; Aston-Jones & Cohen, 2005). This model assumes that task performance is best under moderate levels of LC tonic activation but is hampered by either low levels as well as high levels of tonic activation. If young children have low basal levels of tonic alertness, receiving a warning tone prior to having to respond to a target may help them to reach the optimal (i.e., moderate) level of alertness associated with best performance, which in this case is indicated by lower flanker interference scores. In contrast, warning cues have a harmful effect on task performance when subjects already show an adequate level of alertness in the absence of warning signals. In this case, the alerting tone leads to worse conflict processing due to either faster but poorly contrasted responses (Posner, 1994) or enhanced processing of flankers (Weinbach & Henik, 2012). Thus, the relationship between basal tonic alertness and level of performance may underlie the observed interaction between the alerting and executive attention networks in children.

3.7 Concluding remarks

The ANT has been widely used to study the function of the attention networks since it was first introduced (Fan et al., 2002). A child version of the task was published two years later to study the typical development of attention (Rueda et al., 2004). This task has been extensively used to examine attention function in developmental disorders (Houwink, Aarts, Geurts, & Steenbergen, 2011; Johnson et al., 2008; Kratz et al., 2011), and to examine the effect of environmental (Mezzacappa, 2004), educational (Tao, Marzecova, Taft, Asanowicz, & Wodniecka, 2011; Yang, Yang & Lust, 2011; Rueda, Checa, & Cómbita, 2012), and other behavioral and neurological (Abdullaev, Posner, Nunnally, & Dishion, 2010; Dye, Baril, & Bavelier, 2007; Quintero-Gallego, Gomez, Morales, & Marquez, 2011) conditions on the efficiency of attention. Despite of the steady increase in the use of the ANT, only a few studies have been carried out to characterize the developmental trajectories of the attention networks in typically developing children, and no prior studies have examined interactions between the attention networks in childhood.

Our results provide further information on the development of the three attention functions during childhood. Alerting showed a significant developmental improvement after age 7, mostly in speed of processing. Executive attention showed increases in efficiency between 7 years and older ages, and further improvements in late childhood. In turn, benefits of orienting on response precision seem to improve considerably between early and late childhood. Further, 6- to12-year-old children also showed interactions between alerting and orienting, and orienting and executive attention, which are observed in adults. This suggests that these interactions build up from mechanisms that are inherent to the way the attention networks are connected with each other in the human brain. On the other hand, the effect of the state of alertness on the accuracy of conflict processing appears to evolve according to children gains on the capacity to endogenously sustain alertness with age.

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Chapter 4.

Attention-training series.

4.1 Behavioural and neurocognitive effects of attention training

4.1.1 Introduction: brain plasticity and development

Throughout development, the emergence of new behavioural and cognitive abilities is dependent on the capacity of the brain to be structurally and dynamically modified by naturally-normative and experience-related factors (Galván, 2010; Johnson, 2001, 2011). Developmental structural changes in children´s brain underlies the maturation of different functional domains (i.e. vision, hearing, attention, language), and through the interaction with the environment improved inter and intra-regional connections are developed (Crone & Richard Ridderinkhof, 2011; Gogtay et al., 2004; Johnson, 2001; Jolles, van Buchem, Rombouts, & Crone, 2012; Mackey, Raizada, & Bunge, 2013). Thanks to the emergence of neuroimaging techniques and advancement in procedures for data processing we are now able to trace the structural and dynamic changes that occurs as part of maturation, and to understand how these changes underlie the progressive improvement in effectiveness of cognitive processes.

Several studies have shown that the development and maturation of human brain structures presents a protracted development following a non-linear trajectory (as indicated by changes in white matter and grey matter density, myelination, synaptic pruning), where structures that supports more basic perceptual and sensory processing mature earlier in life, while structures that supports more complex processes (i.e. language, reasoning, information integration) mature until late childhood and early adolescence (Giedd et al., 1999; Gogtay et al., 2004; Johnson, 2001; Shaw et al., 2006; Thatcher, Walker, & Giudice, 1987). Based on a model proposed by Clansey, Darlington and Finlay (2000), Johnson (2011) suggests that this protracted development constitutes an evolutionary advantage because the more delayed developmental time course of any brain region, the larger the relative volume of the later developed structures (e.g. the pre-frontal cortex). This prolonged developmental trajectory, together with the interaction with the environment, may contribute to the fine tuning and shaping of brain circuitry. For example, in a recent study Shaw et. al. (2006) presented evidence that suggested that the level of intelligence is related to the trajectory of cortical development, especially related to the prefrontal cortex. Authors suggested that the relatively late structural and metabolic maturation, together with the prolonged phase of prefrontal cortical gain in the most intelligent, might be related to a more extended sensitive period for the development of high-level cognitive cortical circuits (Shaw et al., 2006).

Johnson (2011) suggested three main frameworks that could be used to explain data related to human postnatal functional brain development. First, the *maturational framework* seeks to interpret emerging functions in terms of degree of maturation (in relation to the adult state of functioning) of a particular brain region. Second, the *skill-learning framework* proposes that the brain regions active in children during the onset on new abilities are similar to those in complex skill acquisition in adults. Third, the *interactive specialization framework* proposes that, throughout development, activity-dependant interactions between cortical regions refine their functions and response properties by narrowing the circumstances by which they are activated, and at the same time inducing organization of patterns of inter-regional interactions. Although there is an on-going debate regarding which of this frameworks could best account for the structural and functional brain changes related to development, there is a common principle between them: the specificity and specialization of brain regions is related to experience-dependant processes (Casey, Galvan, & Hare, 2005; Galván, 2010; Hillman et al., 2012; Johnson, 2011; Jolles, Grol, Van Buchem, Rombouts, & Crone, 2010). Therefore its important to understand the way environmental influences (i.e. social interaction) may influence the development of cognitive processes.

4.1.2 Social influences on the development of cognitive control

Besides the natural-normative development that in general follows the norm of the species, brain plasticity also emerges from learning and experiences that are specific to each individual (Galván, 2010; Mackey et al., 2013). One research tradition that has been interested in study the social genesis of higher cognitive processes it's the cultural-historical tradition that started with the Russian psychologist Lev S. Vygotsky. One of the fundamental principles from this model its that children´s cognitive development is not only related to the normative natural development, but it occurs within the context of social interaction and communication with adults and more capable peers (Bodrova et al., 2011; Luria, 2002; Vygotsky, 1997).

For vygotskians, one of the key elements that foster the emergence of more complex forms of self-regulation and reasoning abilities it´s the used of language as an instrumental tool for organizing one's own behaviour (Bodrova et al., 2011; Vygotsky, 1997). Bodrova, Leong and Akhutina (2011) suggests that children can focus their attention by means of labelling objects or direct their problem-solving activities by engaging in external and later internal private speech.

Vygotskians explains that in the process of the development of higher mental functions there is a series of stages that are needed in order to form a new structural-functional system (Bodrova et al., 2011). First there is a stage where the initiation and execution of an action its originated trough a social interaction (i.e. if you want to do it better you should pay attention to….). Then individuals are able to issue and execute self-commands (i.e. I should focus on…), constituting in this way the second stage, the extra-mental stage. Finally in the intra-mental stage, the voluntary action it's internalize and execute without the explicit command. The nature of the different components of the resulting structural-functional system is determined by the nature of social mediation existing primarily in the form of language (Luria, 1965, 2002). The process by which and adult assist the children when doing a task by means of language, has been referred to as scaffolding (David Wood et al., 1976).

A study conducted by Robinson et. al. (2009) assess the influence of maternal scaffolding in children´s regulation of attention. In these study children had to perform a puzzle-matching task first with the mother (parent-child task) after which they had to do it by themselves (alone task). Results indicate that children with poor performance in the parent-child task but that receive the most amount of scaffolding, manage to translate this support into self-regulation abilities that where evident in an improved performance while doing the task alone, while children with initial poor performance in the parent-child task and with low scaffolding show poorer performance at the moment of doing the task alone (Robinson et al., 2009). These results suggest that verbal scaffolding provides the necessary input to enable the emergence of more efficient mechanisms of attention regulation in the child. However, it's not clear how the internalization of a verbal command it's transformed into an element that promotes cognitive regulation skills.

In order to understand the way that language and cognitive processes interact and influence each other´s, it´s important to find a framework that enable the integration of both aspects in terms of self-regulation. We proposed that the framework of metacognition is suitable for this purpose.

4.2.3 Metacognition and cognitive control

Metacognition refers to the awareness, monitoring and control of one's own cognitive processes and to the knowledge that we have regarding this mechanisms (Efklides, 2008; Flavell, 1979, 2000; Shimamura, 2000). Within the *metacognition framework* there are two main components that are considered important for the regulation of cognition and behaviour: Metacognitive Control (MC) and Metacognitive Knowledge (MK) (Efklides, 2008).

Metacognitive control has been related to the processes that coordinates cognition by implementing top-down regulation of information processing (Fernandez-duque et al., 2000b; Shimamura, 2008) and makes use of strategies in order to control cognition (i.e. procedural knowledge) (Efklides, 2008).

Shimamura (2000) suggested that MC it's linked to aspects of executive functions because both enable top-down modulation of cognitive processes in order to produce voluntary goal oriented behaviour such as selective attention, working memory, inhibitory control, conflict resolution, task switching and cognitive monitoring. It has been also suggested that both cognitive control mechanisms are associated with a set of brain structures that has been related to executive functions, such as the anterior PFC, dorso and ventro lateral PFC, dorso and ventro medial PFC, orbito frontal cortex and the frontal eye field (Botvinick et al., 2004; Fernandez-duque et al., 2000b; Shimamura, 2000, 2008).

Metacognitive Knowledge (MK) it's a construct that consist in the knowledge that the individuals has about cognition in general, and about their own cognitive abilities (Flavell, 1979; Schraw & Moshman, 1995). In other words, MK consists of the knowledge that an individual has about which factors and skills can influence their performance (i.e. declarative Knowledge), which proceedings are necessary to execute these skills (i.e. procedural knowledge), and how and when to apply this actions in order to accomplish optimal performance (i.e. conditional knowledge) (Schraw & Moshman, 1995).

A dynamic interaction between MC and MK its established by the continuous updating and enriching of MK by the information coming from the conscious monitoring of cognition, by observing the results of owns own and other people's actions and by interacting and communicating with others (Efklides, 2008). In this process language plays an important role, because its trough language that a person is able to communicate the content of their awareness, reflect, draw inferences, and make attributions about the relations between inner states and observable behaviour and action outcomes. In turn, the updating of MK helps to improve the metacognitive model of the current task in order to implement more effective cognitive control in order to achieve optimal performance (Schraw & Moshman, 1995).

Therefore it is important to considered how the interaction between both MC (or cognitive control mechanisms) and MK influence children's development of self-regulation mechanisms and its underlying brain dynamics. Also, by studying these interaction it is possible to gain new insights into the mechanisms that promote the improvement in efficiency of cognitive processes, as well as their deficiency in different neuropsychological conditions (Baym, Corbett, Wright, & Bunge, 2008; Crone, Wendelken, Donohue, van Leijenhorst, & Bunge, 2006; Groom et al., 2010; Krain & Castellanos, 2006; Lamm et al., 2006; Rueda, Posner, et al., 2004; Todd, Lewis, Meusel, & Zelazo, 2008; Wright, Matlen, Baym, Ferrer, & Bunge, 2007).

4.1.3 Cognitive training as a tool for studying brain plasticity and its relation with improvement of cognitive processes.

One approach that has proven to be useful to assess the influence of experience and environment on the development and improvement of control mechanisms is the study of cognitive training effects on behavioural and neurocognitive measures of cognitive control processes. Jolles and Crone (2012) proposed that theory-based cognitive training studies improve our understanding of the specific functions that are being trained and why these functions are sometimes compromised. Therefore, the evidence provided by training studies could offer further insights into the developmental trajectory of cognitive processes, as well as the influence of environmental factors on functional-structural changes that may underlie such effects.

In general, training approaches are classified as either process-based or strategy-based paradigms (Jolles & Crone, 2012; Lustig, Shah, Seidler, & Reuter-Lorenz, 2009). The process-based approach consists in training specific cognitive processes and are based on repetition of a demanding executive function task whereas the strategy-based approach is concerned with providing the necessary instructions to develop metacognitive knowledge about task relevant procedures and strategies (Jolles et al., 2012).

There have been a few studies that examined the effects of process-based cognitive training in children using neuroimaging techniques (Jolles et al., 2012; Rueda et al., 2012; Rueda, Rothbart, et al., 2005; Stevens, Fanning, Coch, Sanders, & Neville, 2008). An advantage of neuroimaging data is that it can be analysed along several dimensions (e.g. amplitude, latency, location, and dynamics of activation and connectivity) which are thought to provide greater sensitivity compared to behavioural results (Jolles & Crone, 2012; Lustig et al., 2009). Studies conducted with children with dyslexia have shown that experience and practice produce beneficial effects by normalizing patterns of brain activation in areas related to language processing (Shaywitz et al., 2004; Simos et al., 2002; Temple et al., 2003). In other study, Jolles et al. (2012) showed that children who participated in a working memory training program show increased working memory capacity (i.e. the working memory task, digit span test) as well as increased activation in a fronto-parietal network (i.e. DLPFC, anterior insula and superior parietal cortex) that matched the activation observed in adults, suggesting that children show more adult-like brain activation after training.

Convergent evidence is presented by studies using event-related potentials (ERP) to study the effects of attention training program in preschool-age children. The EEG/ERP technique allows measuring the activation of the brain related to processing particular stimuli with great temporal resolution. Rueda et al. (2012) conducted a study using ERPs to assess the impact of an attention-training program in cognitive and brain processes related to executive attention (i.e. conflict monitoring). Replicating previous results (Rueda, Rothbart, et al., 2005), results of this study showed that training influences both timing and topographic distribution of the ERP's related to conflict monitoring. They found that trained children show a decrease in latency of conflict processing effects in ERPs and a shift in the topography of such effects from anterior to more posterior leads (Rueda et al., 2012). Moreover, the pattern of brain activity showed by trained children was maintained in a two-month follow-up test. Interestingly, in this study trained children did not show near-transfer effects to behavioural measures of performance in a child-friendly version of the flanker task, supporting the idea that training related changes may be easier to detect at the neural than the behavioural level.

In the past years, the process-based approach has been the most used in training studies. The reasons for this may be because these approach enables the experimenter to control several variables that would provide more specificity and accurate mapping of the cognitive changes and the underlying structural and dynamic brain modification the cognitive processes that are targeted by the training. However, there are studies that have assessed the impact of strategy-based cognitive training programs in children by using well-structured school curricula specifically designed to improve cognitive control mechanisms.

Diamond et al. (2007) conducted a study to examine the impact of one curricula-based program designed to improve cognitive control processes (i.e. executive functions). The program they used, named "Tools of the Mind" is based on Vygotsky's cultural-historical theory of development (Vygotsky, 1978), and includes activities that promote executive functions skills. Training activities include self-regulatory private speech, dramatic play, and aids to facilitate memory and attention (A. Diamond, Barnett, Thomas, & Munro, 2007). Results of this study revealed that children who participated in the Tools of the Mind curricula showed a significant improvement in accuracy measures in demanding executive functions tasks (i.e. conflict monitoring and inhibitory control), compared to children in non-trained control group. There are other curricula-based studies that also report improvement in cognitive control mechanism (Lillard & Else-Quest, 2006; Raver et al., 2008; Riggs et al., 2006), unfortunately none of these studies have collected neurocognitive data that would help understanding the brain mechanisms underlying changes produced by strategy-based training programs.

To our knowledge, no prior studies have examined the impact of combining process-based and strategy-based approaches of cognitive training. Therefore, the present experimental series has been conducted with the aim of deepen our understanding of the impact of environmental influences on cognitive control mechanisms and higher mental processes (i.e. intelligence). In order to do that we conducted a series of experiments where we assess near and far-transfer effects of an attention training program in measures of executive attention, executive function and intelligence. Moreover, we want to evaluate the beneficial impact combining the processes-based and strategy-based training approaches on the development of executive attention. To address this we compared the effects of the combined training with the effects of a process-based training approach.

Our processes-based training it's based on computerized training exercises that were designed to training attention processes, and has been used in previous studies (Rueda et al., 2012; Rueda, Rothbart, et al., 2005). The strategy-based approach it's based on the implementation of metacognitive scaffolding designed in order to assist children by means of a reflexive feedback. Based on Vygotsky's (1978) principle of the Zone of Proximal Development the metacognitive scaffolding its designed to provide children with the necessary support for the emergence of the abilities needed to improve MK, by encouraging children to reflect on their own performance through the use of a reflexive-feedback. The feedback was carefully design to provide a framework to guide the trainer in the establishment of a verbal interaction with the children, in order to direct the child in the processes of collecting information about task relevant features, structuring this information in a metacognitive model, and organizing the steps to implement the necessary actions that would help them increase their performance during training exercises. This feedback-guide was design for each of the training games modelling a dialogue between the trainer and the child.

By comparing the effects of combined and process-based training we expect to found effects that would provide evidence on how the different training strategy impacts in near and far-transfer effects, as well as the influence on brain activation that underlies such changes.

4.2 Materials

4.2.1 Assessment tasks

4.2.1.1 Behavioural Measures

To assess possible behavioural near and far-transfer effects of the attention-training program we used a set of pen and pencil tests, which provided measures of inhibitory control, working memory and intelligence.

As a measure of inhibitory control we included the Simon Says test (Strommen, 1973) that has a similar principle as the Go/NoGo task. In this task, children has to inhibit a predominant response when a Go cue is missing. The task is presented as a game in which the experimenter performs a series of motor actions while giving the matching verbal instruction (e.g. "*touch your knees*") to the child. Children are asked to follow the command and imitate the experimenter only if the instruction is preceded by the words "Simon Says". An example of a Go trial is "Simon says touch your head", whereas only saying "touch your head" would be a NoGo trial. The task consisted of 20 trials (50% NoGo). Experimental trials began only when it was clear that the child understood the instructions. Percentage of inhibition errors was calculated and included in the analyses as a measure of inhibitory control.

We included the *Working Memory Span Subtest of the* WISC (Wechsler, 1991) as a measure of working memory. This test is composed by to subtests: Forward and Backward memory span. Children are instructed to listen and repeat series of digits in the same (Forward) or reverse (Backward) order of presentation. A total of 8 experimental blocks are presented, including two trials (series of numbers). The amount of numbers in the series gradually increases in each block from 2-digits series up to 9-digits series in the last block. The task terminated once the child committed two consecutive errors within the same block. The number of correct trials (series of digits correctly remembered) was registered for each condition and used as dependent variable.

We also included the Kaufman Brief Intelligence Test (K-Bit; Kaufman and Kaufman, 1990) to examine far-transfer effects into measures of fluid reasoning (Matrices), crystallized (Verbal) and a composite intelligence (IQ) score.

4.2.1.2 Neurocognitive Measures

To examine the impact of the attention training program on brain function we used cognitive tasks based on classical paradigms widely used to target conflict monitoring (Flanker task) and inhibitory control (Go-NoGo) procesess, while registering the electrophysiological activity of the brain (EEG). A complete description of these tasks is provided in the experimental series section for each EEG study.

4.3 Training program

The training program used in our study is similar to the one used by Rueda et al (2005; also described in Rueda et al., 2007 and Rueda et al., 2011).

The program consisted of 14 computerized exercises divided into 6 categories: (1) Tracking/Anticipatory; (2) Attention Focusing/Discrimination; (3) Conflict Monitoring/Resolution; (4) Inhibitory control; (5) Task Switching; and (6) Sustained Attention. For the current study, we designed three additional exercises that were included into the category of Conflict Monitoring/Resolution, one in the category of Inhibitory Control and another one in a new category of Task Switching. The exercises consisted on tasks with increased levels of difficulty, and in order to progress from one level to the next, the child must complete a minimum of correct trials in a row (see table 4.1.1 for detailed description of the training program).

Exercises included in the *Tracking/Anticipation* category were designed with the purpose of training children to track and monitor the trajectory of a cartoon character trough the screen by using a mouse. In the *Side* exercise the child is asked to take a cartoon cat to the grass while avoiding going into the mud. As the game progress through higher levels, the mud area gets progressively bigger and the grass area gets smaller, increasing the attention and movement control requirements. In the *Maze* exercise, children help a cartoon cat to get food by navigating it through a maze to where the food is. Finally, the *Chase* exercise requires anticipating the location where a duck that swims across a pond in a straight line will come across in order to catching it. For that purpose, the child manages the movement of a cartoon cat through the computer screen. In most difficult levels of the exercise (Chase Invisible), the duck becomes invisible when it goes into the pond, as if diving, so that its trajectory remains invisible.

The *Focusing/Discrimination* category has two types of exercises. The first exercise consists on a matching-to-sample game in which children have to click on the one of two pictures that looked exactly the same as a sample picture. Similarities between the two options increased progressively, requiring the child to pay closer attention to characteristics that become less salient. This exercise has two versions. In the first version (named *Portraits*) the sample picture remains on the screen while the child selects the matching item. In the second version (named *Portraits Delay*) the sample picture disappears after a short interval, forcing the child to keep in mind the attributes of the sample picture. The second type of exercise (*Shapes*) consists on the presentation of a number of overlapping figures that requires children to discriminate and determine which are the figures presented by clicking on the appropriate buttons displayed on the sides of the screen. Difficulty is augmented in successive levels by increasing the number of overlapping shapes and the complexity of combinations of patterns and colour of the displayed shapes.

The *Conflict Monitoring/Resolution* exercises consisted on Stroop-like games with numbers. In the first one (*Numbers*), children are presented with two sets of items and their task is to click in the group composed by the larger amount of items. In the firsts levels of the exercise, sets consist of pictures of fruits and the number of items in each group differs by a large amount (e.g., two compared to eight). As the child progress through the levels and difficulty increases, the two sets are made of digits, and therefore trials can be congruent when the larger set of digits is formed by digits of higher value (e.g. four numbers 8 vs. two numbers 1), or incongruent when the larger set of digits is formed by digits of smaller value (e.g. six numbers 2 vs. four numbers 9). The second Stroop-like exercise (*Value, not size!*) also involves numbers, but in this case the conflicting dimensions are value and size. In successive trials, various numbers (either two, three or four), which differ in size, are presented, and children are asked to click on the number of higher value disregarding the size. Again, there can be congruent trials where the larger number is the one with higher value, or incongruent trials where the larger number is not the one with higher value. Before performing these exercises, children completed another exercise in which their knowledge of Arabic digits was practiced.

There are two exercises included in the category of *Inhibitory Control*. The first one, the *Farmer* game, consists in a Go/No-Go game in which the child's job is to help a farmer taking sheep inside a fence. The trial starts with a picture of a bale of hay displayed in the middle of the computer screen. Children click on the bale of hay to find out whether the animal behind it is a sheep or a wolf. If the animal is a sheep, the child is to click as quick as possible to make it go inside the fence, whereas the response must be hold to the wolf. In advanced levels, a stop signal was included in the form of a wolf dresses-up as a sheep that after a short interval losses its mask and reveals its identity, making the response inhibition more challenging. The second game included in this category, named *Robots*, is also a game based on the Go/NoGo paradigm. In this exercise, children were asked to feed the robot by pressing space bar when the shape of a metal cookie (i.e. triangle, square or circle) matched the shape (also triangle, square or circle) of the robot (Go trials), and to withhold the response when the shape of the cookie and the robot did not match (No-Go trials). The Go/NoGo trials ratio varied from 65/35 to 80/20 respectively. The increase on difficulty of the exercises is established by the following parameters: a) variability of the NoGo stimuli (from frequent to more infrequent), b) change of the robots shape within each block (some blocks had only robots of one shape whereas in successive levels robots of different shapes were mixed within a block of trials), and c) by presenting stop-signal "cookies", which consisted on shaped-matched cookies presented in a greenish color. The child was instructed to not press the button to this type of cookie even when matching the robot shape because the color indicated that they were spoiled.

The *Professor* exercise conformed the new category of *Task Switching*. In this exercise, children had to classify items that where displayed in a blackboard according to a rule provided by a professor. The items could be sorted by colour (red, blue), shape (square or circle) and size (big or small items). The difficulty of each level was manipulated by changing parameters related to the amount of changes in each block (2, 4, 8, 12), the sequence of changes (fixed or random sequence), and by combining two different dimensions within the item to be classified (e.g. the professor ask to classify items by shape, and the item presented contains two circles one small-red and one big-blue).

Finally, the *Frog* exercise, within the category of *Sustained Attention*, consisted of a game in which children are asked to help a frog catch flies that come out of a transparent bottle at a particular time rate. The child must press a key as fast as possible in order to unroll the frog's tongue and catch the fly. In some trials, the fly makes a noise before coming out of the bottle (a warning/alerting signal). The requirement to sustain attention is increased across blocks of trials by enlarging the interval of time between flies, and by varying the frequency of the warning signal.

4.4 Metacognitive Feedback Script

As has been described in previous sections, the metacognitive feedback script is build upon the principles of Vygotsky's cultural-historical theory, with the goal of fostering the metacognitive knowledge. The principal idea of the feedback is to establish a dynamic dialogue between the trainer and the children that would serve as instructional scaffolding with the purpose to provide a deeper level of learning of the characteristics of each exercise within the program and the strategies to solve them. According to Vygotsky's theory of development, scaffolding contributes to achieve the most of the developmental potential within children Zone of Proximal Development.

The Metacognitive feedback script was designed with the purpose to provide a framework that allows the trainer to promote children metacognitive knowledge through scaffolding. The idea is to promote children's ability to create metacognitive models of important task features that would help them to improve their performance on the different exercises included in the training program. Trough the extraction of important task features, children would be able to improve their declarative knowledge about each exercise, promoting the awareness of features most useful for the correct completion of the task.

The metacognitive scaffolding was elaborated in the form of a feedback dialogue. It was composed by questions aiming to direct children attention to specific stimuli characteristics and to promote reflective thinking regarding their performance. During the child-trainer interaction, the trainer encouraged children to externalize their thoughts, using the dialogue to assist children reasoning in order to establish a causal relationship between the importance of paying close attention to task features and their behavioural improvement. Additionally, children were encouraged to anticipate the possible actions to be performed in order to success in each exercise, thus fostering the procedural knowledge of each exercise.

With this procedure, we expected to enhance children's conditional knowledge by promoting the creation and internalization of metacognitive models of task features. Also, by using metacognitive feedback will help children learning how to apply this knowledge to improve their cognitive control abilities. We expected that this training strategy would promote children's reasoning abilities, due to the strong reasoning component present in the reflective dialogue. For an example of the metacognitive feedback script for the exercise of Portraits see Anex #, and for all the games see Anex # (only in Spanish).

	Exercise	***Trained process***	***Brief Description***	***No. Levels***	***No. Trials***	***Advance Level Criterion***
1	Side	Target tracking	Navigating a cartoon cat to reach areas of grass and avoid muddy areas, which get progressively bigger	7	At least 7 trials per game.	Successfully get the cat to the grass.

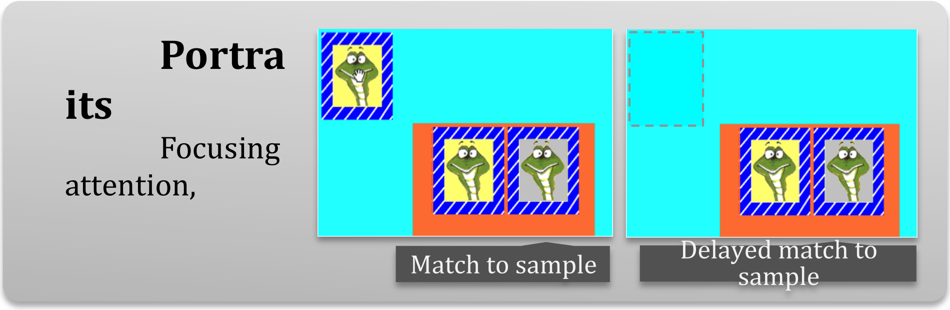
	Chase	Target tracking, anticipation	Anticipating where a cartoon duck that swims across a pond in a straight line will come across in order to chasing it. In the highest levels of difficulty, the duck dives so that its trajectory remains invisible.	7	At least 3 per level.	
	Maze	Anticipation	Navigating a cartoon cat through a maze to get food.	6	At least 6 trials per game.	Successfully complete the maze.
2	Portraits	Focusing attention Perceptual discrimination Working memory	Matching-to-sample exercise with cartoon pictures. Requires clicking on the one of two pictures that looks exactly the same as the sample picture. In higher levels, the sample picture disappears before the two choices appear on the screen and the child is to keep in mind the attributes of the sample picture.	7	At least 3 per level.	Successfully match the target picture with the sample picture 3 times in a row.
	Shapes	Focusing attention Perceptual discrimination Working memory	A number of overlapping figures are presented and the child has to determine which are the ones presented by clicking on the appropriate buttons displayed on the sides of the screen.	8	At least 3 per level.	Successfully discriminate the shapes presented on the screen 3 times in a row.
3	Numbers	Conflict monitoring Conflict resolution	Two sets of numbers are presented and children have to click in the group composed by the larger amount of items. Trials can be congruent (larger group made up of numbers of higher value) or incongruent (larger group made up of numbers of lower value)	6	At least 9 per level.	Successfully choose the correct set of numbers 9 times in a row.

	Value-not-size	Conflict monitoring Conflict resolution	Various numbers differing in size are presented on the screen. Children are asked to click on the number of higher value disregarding the size. Size and value can be congruent (the higher number is the larger in size) or incongruent (the higher number is the smaller in size).	7	At least 3 per level..	Successfully choose the correct set of numbers 3 times in a row of the incongruent trials.
4	Professor	Conflict Monitoring Cognitive Flexibility	A picture of a shape having three different dimensions of the stimuli: Shape (round, square), Colour (red, Blue), Size (big, small), has to be sorted in a different basket dependent on the instruction given by the professor. Children are asked to click on the correct basket to sort out the object in dependence of the instruction. Instructions changes during each run in order trigger cognitive flexibility processes.	7	27 trials per level.	Successfully choose the correct basket 4 times in a row per level, without committing an error.
	Farmer	Inhibitory control	Cartoons animals (either sheep or wolfs) appear behind a bale of hay and children are asked to quickly click only to sheep in order to bring them inside a fence.	7	66 in total 3 runs each level 12 trials min and 24 max per run	Successfully get all the sheep's into the fence in three consecutive runs, without committing an error.
	Robots	Inhibitory control	Children are to feed robots with metal pieces according to their shape and colour in a fast pace. They must avoid feeding each particular robot with pieces of non-corresponding shape/colour.	7	At least 36 trials per level.	The participant should complete all the trials of each run. If a mistake is committed the run count starts again.
5	Frog	Sustained attention Preparation	The child must press a key as fast as possible in order to help a frog catching flies that come out of a bottle. The requirement to sustain attention is increased by enlarging the interval of time between targets, and presence/absence of warning signals.	7	24 trials per level.	The participant should complete all the trials of each level, without committing an error.

Table 4.1.1. Description for each exercise used in the attention-training program.

Example of metacognitive script for two of the trainign excercise

Excercise 8. Portraits: Delay match to sample



In this game the child will be presented with a an image composed by two different pictures of animals. In each trial, the child chould first make a click in the orange square at the center of the screen. After having click on it, a picture will apear at one of the upper corners of the screen. Then the child should click on this picture. After this, two more pictures will appear at the orange square, one matching the target picture and one different.

This pictures can present different features from the target trials related to: the identity of the animal, the background color of the picture, the frame color, the orientation of the white lines at the frame, and specific features of the animal presented. The child will get feedback if he wa accurate (claping sounds) or if there was a mistake (and "Oh, Oh" sound).

Procedure to apply the Metacotnitive feedback

Trainerr: *Very well, we will now do a different game… to be able to start the game you should clock on the orgage square at the center of the screen… lets see what happend…*

Child: *there is an orange square and the picture of an animal!...*

Trainer: *very well!... now, take a close look at the image of the animal… and tell me what are the elements of the pictures…. But you hould tell me all the details that the picture has!....*

- *At this point its very important that the child will point out every one of the details that the picture has… the frame color, the background color, the white strips at the frame, their direction… In case the child miss to point out any of the details, they should be guided with reflexvie questions so they should be able to spot the features by themselves… This guided detection its important for the metacognitive scaffolding and the reflexive dialogue regarding error* *detections... "if the child doesn't know what to focus on, how he/she should now that he/she comiited a mistake"...*

Chidl: the picture has a blue color frame (or red)... an animal (bear, jiraffe, snake...)....the background color is yellow (or gray)....

Trainer: point out to the picture.... And remark very well!, but there are something that you have not tell me... what does the frame has on it?.... which direction tehy go?...

Child: haaa... this i didn't notice... well the frame its blue... and it has white stripes that goes to the right....

Trainer: great!... i want you to remember very well that you have to pay close attention to every detail, because what you have to do is to see which of the pictures that would appear next its exactly the same as the picture at the corner and click on the exact one... to see the two picture you have to click on the picture of the corner, and you wil see that two picture will appear at the orange square... ok make a click on the picture an we will see what happend... ok now let me know which one its exactly the same as the one at the corner....

Child: this one!...

trainer: great, that's right!...tell me why they are the same?

Child: because the color of the frame are the same!...

Trainer*: very well!... now let me know which other details you have to pay attention?.... remmeber that we have point them out before?...(the child must remember each and one of the details, if he is unable to remember point out the detail and make a reflexive question)...*

Child: color of the frame, the background color, the white stripes directions....

Trainer: very well, remember that you ahve to pay attention to this details so you can choose the correct picture... come on let's play!.... lets click on the correct picture...dis you see what happend!...

Child: yes!.. they clap...

Trainer: that's right... that's because you did it right!... the game will let you know if you did it right or if you commited a mistake.... Come on let's play!...

Level 2 and subsequent levels

The first three levels, the pictures are different in several features, which makes more easy that the detection of the differences . However, in subsequent levels the difficulty its increased due to the decrease of features that are different and also the decrease of salience of this feature In the last levels, the differences are very subtle and are related to the picture of the animal itself, so one must guide the child to discover and pin point this picture differrences.

Qhen the child makes a mistake, apply the metacognitive scaffolding, helping the child to remember wich features they should pay attention, for example:

- *<u>Child</u>: now what i did wrong? ...*
- *<u>Trainer</u>: maybe you didn´t pay close attention to the picture... lets remember wich thigns you have to see in order to spot the differences... tell me which one's... (now its important not to point them out, but that the children its able to express them verbally by themselves).... In case they forget to mention one remark: hey but you have forgot one... which one?.... in case the child its not able to remember, point them verbally)....*

Excercise 12. Farmer

In this game children's have the task of getting the sheeps into the barnyard while keeping the wolfs outside. In each trial the child needs to make click in the yellow frame. This frame will move and it will show either the sheep or the wolf. When the item its a sheep, the child has to press the botton of the joystick in order to place the sheep in the barnyard. When the item is a wolf, the child has to whithold the pressing of the botton to avoid getting the wolf into the branyard. In higher levels, the wolf will have a sheep costume that will make it resemble to a sheep, this costume coulde be either incomplete in order to create conflict (only the fur of the body) or will havea a complete costume that will loose the mask after a delay (that would serve as a stop signal).

This game has 12 levels, with 6 groups of trials, that includes several Go (sheeps) and at least one NoGo (wolf) trials. In order to pass to the next level, the child has to accomplish a specified minimun of succesfull trial groups, that is set to each level.

Procedure to apply the Metacotnitive feedback

<u>Trainer:</u> So now we will play another excercise... In this game, all the sheeps from Joe the farmer has scpaed from the barnyard.... And your job is to help Joe the

Farmer to get all his sheeps back to the barnyard… but be carefull, there is a wlf around that would try to get into the barnyard in order to take the sheeps… so se aware to get only the sheeps into the branyard… Th wolfs should stay out!!...

So now, to start playing what you have to do is to click on this block of straw where the animals are hidden behind… in that same spot you will find the animal…. This could be either the sheep or the wolf… so what should we do with the sheeps?...

Child: we have to get them into the barnyard!....

Trainer: great!... only the sheeps goes into the barnyard… and in order to get them, what you need to do is to click on the sheep… in that way she nows she can go in… but be carefull, and remember that theres a wolf around… so whenever the wolf appears do not click on him…. Just wait for a little while and he will run away… but if you click on the wolf then he will go inside the barnyard and will take all the sheeps with him… so you ahve to pay attention so you wont let any wolf inside…. So what should you do in order for the sheeos to come inside the barnyard?...

Child: I have to click on the sheep….

Trainer: Very good!...you have to click on the sheep… and what about when a wolf appears?...

Child: I dont have to do anything… in this way the wolf will run away… (if the child does not answer, or doesn't understand, you should repeat the instructions until the child can express the instructions)…

Trainer: very well…. That's what you have to do… great then lets play!...

Level 2 and subsequent levels

In subsequent levels, the frequency on wich the wolfs shows up its increased. Besides this, it can be that the wolfs appears in a sheep costume, adding more complexity and difficulty to the task. So its important to help the children to reflect on this aspect in order for them to create an strategy that would help them to regulate their behaviour.

In case the child makes a mistake, engage in reflective dialoge. For example:

Child: o again ii make a mistake…

Trainer: i saw it, what happend?... why did you make a mistake?

Child: because i didnt saw that there was a wolf instead of a sheep…

Trainer: and why di that happend?

Child: because i clicked too fast…

Trainer: very well… so what do you have to do in order to not make this mistake again?...

Child: i have to pay more attention and not click to fast… until i have not seen the animal….

Trainer: great!!... lets continue…

- Mistake commited in a trial where the wolf has the sheep costume:

Child: Opps… that was the wolf!!... but why it was dressed like a sheep?-..

Trainer: this wolf is very cleve, and you have to be more carefull now because he knows that you are only allowing sheeps inside the barnyard… so now he got a sheep costume to try confuse you… what do you have to do if theres a wolf dressed like a sheep?...

Child: i don't have to click on the wolf… in this way he would run away… (in case the child dont answer engage into reflexive dialogue in order to help him become aware that there is no difference between the wolf and the wolf in sheep sotume)….

Trainer: very good!!... then you have to be very carefull because now it could be that the wolfs would be dressed like sheeps… let's do it, and pay more attention!!!

4.2 Attention training, Metacognition and transfer of training effects into intelligence measures

4.2.1 Introduction

An increasing bulk of evidence shows that training cognitive skills increases intelligence. Over the past decade, a variety of intervention programs designed to train diverse cognitive functions have been shown to produce gains on fluid intelligence (*Gf*) in young children (Bergman et al., 2011; Neville et al., 2013; Rueda et al., 2012; Rueda, Rothbart, et al., 2005) older children (Jaeggi et al., 2011a; Klingberg, Forssberg, & Westerberg, 2002) and adults (Jaeggi et al., 2008; Jaušovec & Jaušovec, 2012; Karbach & Kray, 2009). Skills trained by those programs often involve one or various of the so-called Executive Functions (EF), such as executive attention (i.e. the ability to detect and resolve conflict between alternative responses), working memory (i.e. the ability to retain and manipulate information for short periods of time) or cognitive flexibility (i.e. the ability to switch from tasks that entail different rules). Gains on intelligence shown by this type of intervention appear to be specific to measures related to reasoning and novel problem-solving abilities, so-called *Fluid* Intelligence (*Gf*), leaving *Crystallized* Intelligence (*Gc*, i.e., acquired knowledge) unaffected (Rueda et al., 2005; 2012;).

Yet, a number of recent researches carried out with adults failed to find improvements in *Gf* after working memory training (Chooi & Thompson, 2012; Harrison et al., 2013; Redick et al., 2013), although in some of these studies the training level attained by participants fall behind the level found in studies showing significant WM to *Gf* transfer effects. Other studies have found transfer effects in some fluid reasoning tests but not in others (Colom et al., 2013; Stephenson & Halpern, 2013), a result that has been used to argue that training does not impact *Gf* at the construct level considering that the effect may be driven by task specific learning (Colom et al., 2013; Shipstead et al., 2012).

The question of whether *Gf* can be improved with training of related cognitive skills is central to issues extensively debated in cognitive science. On the one hand, this research challenges, at least in part, the long believed idea that *Gf* is largely determined by biological endowment and therefore relatively unsusceptible to educational intervention (Cattell, 1987; Horn & Cattell, 1967). However, more recent conceptions of intelligence consider that both genetic as well as environmental factors have an impact on individual differences in intelligence and the brain systems supporting it, and that in fact these two factors may not always be independent from each other (Dickens & Flynn, 2001; Gray & Thompson, 2004).

On the other hand, transfer from EF training to untrained reasoning skills challenges previous data indicating that intensive practice is essentially domain-specific (Lehmann & Ericsson, 1997). For example, in a classic study by Chase and Simon (1973) it was shown that chess experts who show an extraordinary spatial memory capacity for recalling chess positions would not show superior capacity compared to non-experts when the pieces are randomly placed in the chessboard (Chase & Simon, 1973). This study was followed by others showing that following intensive practice to memorize a large amount of items (e.g. up to 80 digits) individuals would not increase the ability to memorize a different type of material, for example, letters (Chase & Ericsson, 1981). Evidence of this sort is difficult to reconcile with recent literature reporting transfer between different EF skills (i.e., near-transfer) or between EF and *Gf* (i.e., far-transfer). For instance, various studies have reported gains on inhibitory control tasks after WM training (Jaeggi et al., 2011a; Thorell et al., 2009), as well as improvements on untrained response conflict tasks after training on task-switching (Karbach & Kray, 2009), in addition to the evidence mentioned above that shows transfer from EF training to untrained *Gf* skills.

A compelling argument in favor of far-transfer between EF and *Gf* is the anatomical overlap of regions underlying these processes. A meta-analysis of neuroimaging studies using tasks entailing diverse cognitive demands within the umbrella of EF (i.e. WM, conflict and response monitoring, novel problem solving and perceptual difficulty) shows activation of a set of common regions in the prefrontal cortex (Duncan & Owen, 2000). Studies addressing the neural bases of intelligence have shown that there is a striking overlap between those regions and the ones activated by general intelligence (*G*) tests (Barbey et al., 2012; Duncan & Owen, 2000; Duncan, 2000; Hampshire, Highfield, Parkin, & Owen, 2012; Hampshire, Thompson, Duncan, & Owen, 2011).

Also, recent theoretical models propose a hierarchical factor structure of *G* suggesting that cognitive control (i.e. perceptual control of interference and conflict) is an important process that supports high-order reasoning skills (Demetriou, Mouyi, & Spanoudis, 2008; van der Maas et al., 2006). A study conducted by Demetriou et al. (2008) examines the relation between processes embedded into hierarchical categories considered to be important components of *G* (i.e. speed of processing, perceptual control and representational processes), as well as to determine what factors explain age-related differences on *G* throughout childhood. In line with previous studies (Conway, Kane, & Engle, 2003; Engle, Tuholski, Laughlin, & Conway, 1999; Unsworth & Engle, 2005), results show that the relation between elements of the higher hierarchical level of representational processes (i.e. working memory, information integration and reasoning) with the general measure of G, is mediated by processes implicated in perceptual control activated by stroop-like tasks (Demetriou et al., 2008). Moreover, results indicate that, throughout development, any age differences in reasoning are related to differences of the executive processes of interference control. These data suggest the possibility of improving *G* by interventions aimed to enhance the efficiency of cognitive control of interference (i.e. executive attention), and offers a theoretical framework that allows the explanation of far-transfer effects from executive control to *Gf* and *G* skills.

Another important question in relation to training is to understand the best strategies that maximize the effect of interventions and boost transfer effects. To address this question, we adopted a theoretical framework of metacognition that conceived efficient self-regulation as the interplay between control mechanisms and self-referential knowledge. Metacognition is a broad term encompassing both knowledge and regulation of cognitive activity, and can be divided in Metacognitive Control (MC) and Metacognitive Knowledge (MK) (Efklides, 2008; T. O. Nelson & Narens, 1994). MC its related to executive functions particularly because both enable top-down modulation of cognitive processes and share underlying neuroanatomy, as seen by activation of frontal structures such as the anterior PFC, dorso and ventro lateral PFC, dorso and ventro medial PFC, orbito frontal cortex and the frontal eye fields (Botvinick et al., 2004; Fernandez-duque et al., 2000b; Posner & Rothbart, 1998; Shimamura, 2008). On the other hand, MK refers to a meta-level awareness about one's own characteristics (i.e. declarative knowledge), the execution of procedural skills (i.e. procedural knowledge), and how to implement strategies to achieve goals (i.e. conditional knowledge) (Goldfus, 2012; Schraw & Moshman, 1995). The interplay between these two metacognitive components may allow more efficient self-regulation abilities by improving the execution of cognitive control through knowledge acquired from the conscious monitoring of cognition.

Different authors have suggested that language and social interaction may play an important role in the development of children's self-regulation abilities and the emergence of MK. For example, Efklides (2008) suggested that language and social interaction plays an important role in the development, improvement, and transmission of MK. Also, Vygotsky (1978) proposed that a milestone in children's development of higher mental functions was the use of language as an instrumental tool. Within the Vygotskyan perspective, through the interaction with an adult, children learn to use language as a tool for organizing and directing their cognitive processes to improve their self-regulation abilities (Bodrova et al., 2011; Vygotsky, 1978a).

Vygotsky (1978) suggested that the influence produced by external agents (i.e. adults, teachers, more capable peers) on children's development of higher mental functions is exerted through what he called the *Zone of Proximal Development* (ZPD). Within this context, adults (or more capable peers) are able to support children emerging cognitive skills by providing a set of tools (mostly of linguistic nature) that supports self-regulation of behaviour and cognition, as well as by re-structuring the situation in relation to children's actual developmental level and modelling strategies of problem solving (Bodrova et al., 2011; Luria, 2002; D Wood, Bruner, & Ross, 1976). Several studies have shown beneficial effects of social scaffolding on the development of self-regulation abilities in pre-term toddlers (Erickson et al., 2013), children from low income families (Robinson et al., 2009), and classroom curricular interventions with typically-developing preschool children (Bodrova & Leong, 2007; a. Diamond & Lee, 2007).

The aim of the present study is to examine the influence of including metacognitive scaffolding on near and far transfers effects of an process-based attention-training intervention (Rueda et al., 2012; Rueda, Rothbart, et al., 2005). Specifically, we hypothesised that the inclusion of a intervention that fosters MK will improve the efficiency of the attention-training program by producing increased far-transfer effects into measures of fluid-IQ due to the high demand of higher cognitive abilities. Moreover, we expect that training influences attention processes in a similar way regardless of training strategy, however we expect to find evidence of larger far transfer effects for children running the intervention combined with metacognitive coaching. We also expected to find evidence that would indicate that the metacognitive intervention would improve children's performance of the program exercises by needing fewer trials and committing fewer errors at the end of training.

4.3 Method

4.3.1 Participants and Procedure

A total of 107 children where recruited from 6 different urban Kindergardens in Granada (Spain), from which 10 children were discarded because they dropped out. Caregivers of all the children gave written consent to be involved in the study after being informed of its general purpose. Prerequisites for participation were having a normal or corrected-to-normal sensory capacities and no history of chronic illness and/or psychopathologies.

Pre and post-training assessment tasks where administrated at the school, were children completed a set of pen & paper tasks including the Kaufman Brief Intelligence Test (K-Bit), Digit Span (Working Memory) and the Simons Says task (Inhibitory Control).

After Pre-training assessments, subjects were pseudo-randomly assigned to either of the training groups or to the active control group, all of them matched by age, gender and average intelligence (see table 1). We have two training groups related to the kind of feedback provided to the children during the training session. The first training group include a Metacognitive Feedback (MF) designed with the purpose of helping children to develop metacognitive monitoring and knowledge trough an interactive "Metacognitive Dialogue". The second training group had a Normal Feedback (NF) in which the trainer only gives feedback related to the performance of the children (i.e. well done, you can do it better). The Active Control (AC) group carried out the first two levels of each of the training exercise and then watch a film to complete the training session time.

The training program is based on a set of computerized exercises for a total of eight, 45-min, sessions that were carried out in a period of 3 weeks (2-3 sessions a week) which where conducted individually for each participant in a quiet room at the school. At the end of the training intervention children of all groups where evaluated with the same procedure describe for the pre-test assessment, within one week after the training concluded.

4.3.2. Materials

4.3.2.1 Assessment tasks

To assess the effects of the attention-training program we use a set of pen and pencil tests that target different cognitive control functions. Following the study conducted by Rueda, et. al. (2011), we use the Kaufman Brief Intelligence Test (K-Bit; Kaufman and Kaufman, 1990) to measure fluid reasoning (Matrices), crystallized (Verbal) and a composite intelligence (IQ) score, the *Working Memory Span Subtest of the* WISC (Wechsler, 1991) as a measure of working memory (WM) and as measure of inhibitory control we included the Simon Says test (Strommen , 1973) that has a similar principle as the Go/NoGo task, in which children has to inhibit the predominant response when the Go cue is missing.

4.3.2.2 Data Analysis

To assess the impact of the training we analyse data using three different strategies. First, to assess training effects we conducted a set of repeated measure ANOVA´s with session (Pre, Post) and Group (MF, NF and AC) as factors with each of the tests scores as dependent measure. In order to compare groups standardized changes were computed (formula: (posttest – pretest) / $SD_{pretest}$) and submitted to an Analyses of Covariance (ANCOVA) with group as IV, Standardized Change as a DV, and pre-test score of the correspondent variable as the covariance.

Second, to explore if the training strategy would have an influence in the performance of the training exercises, we conducted a one-way ANOVA with training group (MF, NF) as factor with total of trials and total of errors (of all program exercises) as DV. This analysis provide us with information to be able to asses whether the different training strategy does influence children´s performance, as well as if the differential effects found in each training group are related to the performance in the training program (i.e. the more trials and/or errors, the more benefit due to repetition) or if they are directly related to the implementation of a different training strategy.

Third, in order to better characterize the impact of the each training strategy we divided the groups in High and Low Performance sub-groups. Performance Level sub-groups were defined with a Z-score split by calculating an average of the pre-test Z-scores of the K-Bit (Total IQ Score), Working Memory Spam (Total WM Score) and Simon Says task (% Errors). With these groups we performed a set of repeated measure ANOVA´s with Group (MF, NF, AC), Performance sub-group (High, Low) and session (Pre, Post) as factors and each test tests scores as DV. This analysis provide us with information that enable evaluation of the impact of the training program in children that presents a “low” and “high” level of development of the processes assessed.

4.3.4 Results

Descriptive statistics of the final sample are presented in table 4.2.1. Children who did not complete the pre and post evaluation sessions, and that have a percentage of error 2 deviations above the mean were excluded from the analysis (*n*= 1 for K-bit and *n*=36 for the Simon Says task). table 4.2.2 presents Pre-test and Post-test session scores (Mean and SD) for each assessment task, and figure 4.2.1 shows standardized gain scores for each assessment task per group.

Group	*N*	*Gender* *Girls*	 *Boys*	*Mean Age (SD)*	*mean IQ (SD)*
Control	33	13	20	63.7 (6.56)	104.7 (12.27)
Met-Fbck	33	14	19	63.4 (7.84)	104.7 (13.89)
Nor-Fbck	31	13	18	63.5 (7.15)	104.9 (14.72)
Total	97	40	57	63.6 (7.1)	104.7 (13.62)

Table 4.2.1. Descriptive statistics for the sample.

4.4.1 Training effects

4.4.1.1 K-BIT.

Results for the Matrices subscale shows a significant main effect of Session (F(1,92) = 9.54, p < .01, $\eta^2_p = 0.10$), indicating an increase of the matrices score in the post-test (M = 108.80, SD = 10.96) compared to the pre-test (M = 105.12, SD = 12.11), and a significant Intervention Group x Session Interaction (F(2,92) = 4.50, p < .05, $\eta^2_p = 0.09$). Subsequent planned contrast indicated that the increase in Matrices score was significant for the MF (F(1,92) = 12.98, p < .001) and for the NF (F(1,92) = 4.78, p < .05) groups. ANCOVA results revealed marginal differences between MF and NF groups (p = .07, Cohen´s D = 0.27), and significant differences between MF and AC group (p < .001, Cohen's D = 0.78) and between NF and AC Group (p < .05, Cohen´s D = 0.45). (see figure 4.2.1.)

For the Verbal subscale score, no significant main effect of session (F(1,92) = 0.78, p = .37) nor Intervention Group x Session interaction was found (F < 1).

4.4.1.2 Working Memory Span.

Analysis for the Direct WM scale score revealed a significant main effect of Session (F(1,94) = 5.81, $p < .05$, $\eta^2_p = 0.06$), indicating an increase in the post-test score (M = 4.37, SD = 1.21) compared to the pre-test score (M = 4.07, SD = 1.17). No significant Intervention Group x Session (F < 1) interaction was found.

For the Backwards WM scale score a marginal main effect of session (F(1,94) = 3.25, p = .07, $\eta^2_p = 0.03$) was found, and no significant Intervention Group x Session interaction (F < 1).

4.4.1.3 Simon Says (Inhibitory control)

Performance on this task was calculated using the percentage of inhibition errors. Children who showed difficulties for understanding the instructions and/or committed above 80% of errors in either session (pre/post) were excluded from the analysis (n = 31). A significant main effect of Session was found (F(1,58) = 11.79, $p < .01$, $\eta^2_p = 0.16$), indicating a decrease of errors in the post-test (M = 21.09, SD = 18.00) compared to the pre-test (M = 30.43, SD = 19.78). No significant Intervention Group x Session interaction was found ($F < 1$). Subsequent planned contrast revealed a significant decrease on errors for the MF (F(1,58) = 4.29, $p < .05$) and NF groups (F(1,58) = 8.23, $p < .01$).

				Pre		***Post***		***Planned Contrast pre vrs post***	***Standardized Gain***
Task	***DV***	***Group***	***Valid n***	***Mean***	***(SD)***	***Mean***	***(SD)***		
KBIT	*Matrices*	Met-Fbck	32	104.8	(14.80)	112.3	(11.12)	12.98 ***	**0.72**
		Nor-Fbck	31	104.1	(13.42)	109.3	(9.69)	4.78 *	**0.35**
		Control	33	106.6	(12.28)	105.7	(12.19)	n.s.	−0.09
	Vocabulary	Met-Fbck	32	107.4	(11.20)	110.8	(12.61)	n.s.	0.2
		Nor-Fbck	31	108.3	(16.35)	109.4	(12.91)	n.s.	0
		Control	33	106.5	(16.09)	106.3	(15.76)	n.s.	−0.01
Working Memory	*Forward*	Met-Fbck	33	4.4	(1.13)	4.6	(1.32)	n.s.	0.15
		Nor-Fbck	31	3.8	(1.15)	4.3	(1.08)	5.81*	**0.45**
		Control	33	3.9	(1.19)	4.2	(1.19)	n.s.	0.18
	Backwards	Met-Fbck	33	2.2	(1.27)	2.5	(1.14)	2.92≈	*0.23*
		Nor-Fbck	31	2.0	(1.39)	2.1	(1.30)	n.s.	0.16
		Control	33	1.8	(1.14)	1.9	(1.26)	n.s.	0.03
Simon Says	*% Inhibition Error*	Met-Fbck	21	28.0	(18.60)	18.6	(19.30)	4.29*	**0.51**
		Nor-Fbck	23	32.6	(20.27)	20.0	(15.07)	8.23**	**0.62**
		Control	17	30.6	(21.35)	24.7	(20.34)	n.s.	0.28

Table 4.2.2. Mean and Standard Deviation (SD) of the Pre and Post test scores for all the Pen and Pencil assessment tests. Planned contrast indicates the f value for the significant comparisons between pre and post test scores.

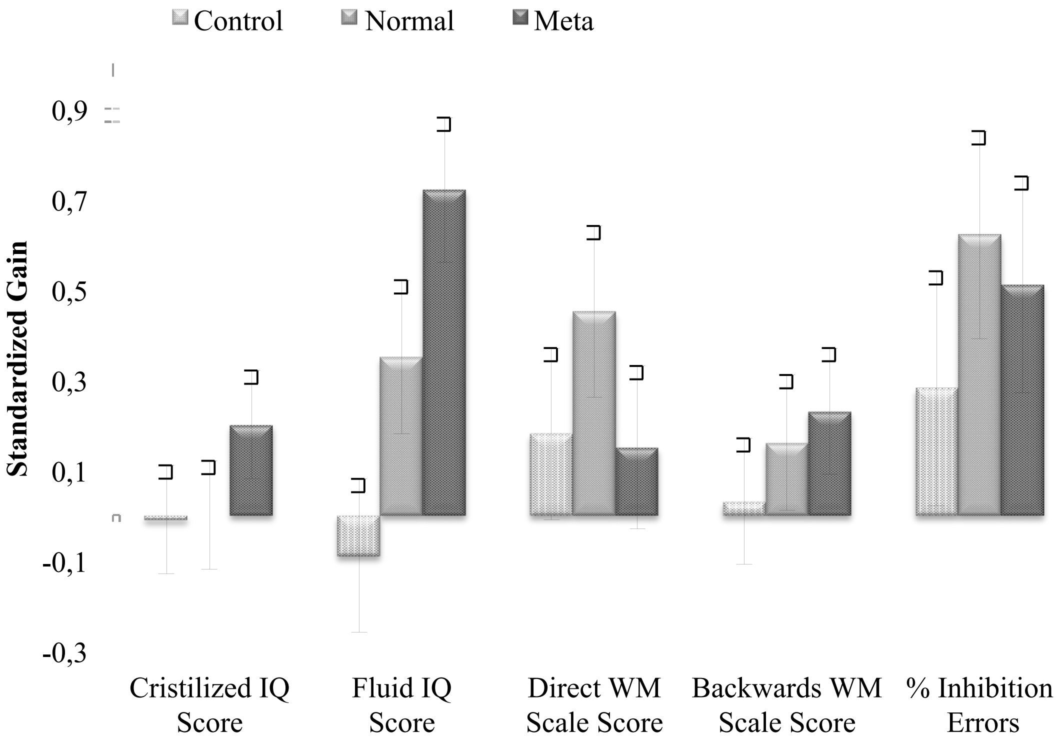


Figure 4.2.1. Standardized gains scores in each test per training group.

4.4.2 Training Performance

Training Performance was assessed only for the trained groups by means of a One Way ANOVA, using total of trials or total of errors as DV. Results revealed a significant difference in total errors ($F(1,62) = 4.16$, $p < .05$, $\eta^2_p = 0.06$) and in total of trials ($F(1,62) = 3.72$, $p < .05$, $\eta^2_p = 0.05$) indicating that children in the MF group committed less errors ($M = 168.54$, $SD = 81.84$) compared to children in the NF group ($M = 217.71$, $SD = 109.74$) and needed less trials ($M = 1079.21$, $SD = 291.25$) than the NF group ($M = 1192.38$, $SD = 151.66$) in order to complete the program (See Figure 4.2.2).

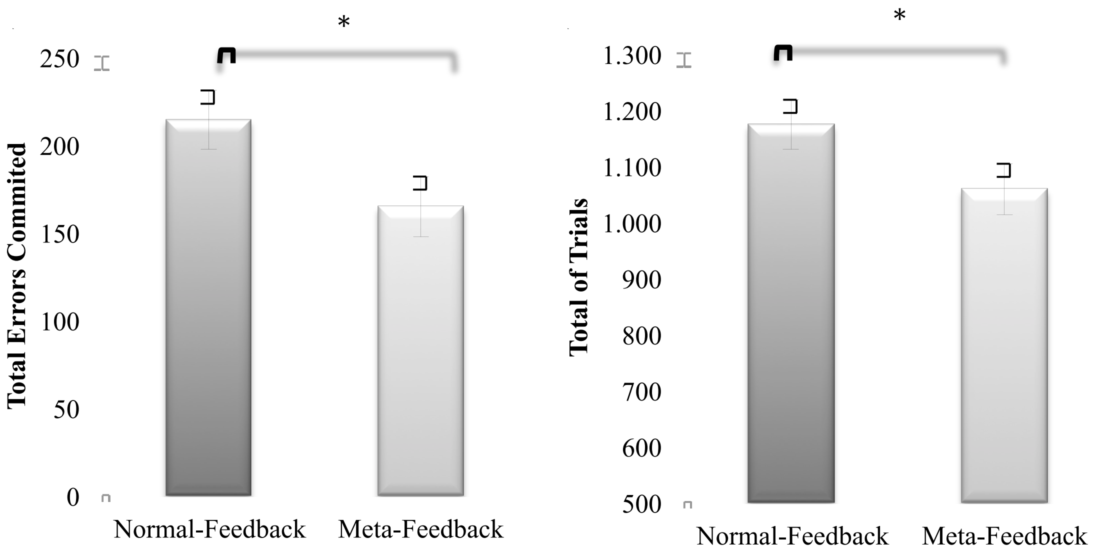


Figure 4.2.2. Performance in all training exercises is illustrated for total of a) errors and b) trials. Graphic shows that MF group needed less trials and committed less errors throughout all training.

4.4.3 Analysis of training based on performance level

In order to further characterize the effect of training on inhibitory control working memory and intelligence measures we divided groups based on their performance at the pre-training session. With this strategy we want to assess the impact of training strategy related to the development already reach by the children and to evaluate the influence on children´s zone of proximal development (see table 4.2.3).

Task	*DV*	*Group*	*Performance*	*Valid n*	*Pre*		*Post*		*Planned Contrast pre vrs post*	*Standardized Gain*
					Mean	*(SD)*	*Mean*	*(SD)*		
KBIT	*Matrices*	Met-Fbck	Low	14	102.0	(10.22)	110.3	(12.06)	6.33*	0.65*
			High	18	105.2	(11.18)	112.4	(9.00)	6.73*	**0.57**
		Nor-Fbck	Low	15	99.6	(11.00)	106.4	(8.55)	4.80*	**0.62**
			High	16	109.4	(13.70)	112.2	(10.11)	n.s.	0.25
	Vocabulary	Met-Fbck	Low	14	99.4	(17.43)	104.5	(15.42)	3.11≈	**0.27**
			High	18	113.1	(9.75)	115.1	(8.38)	n.s.	0.09
		Nor-Fbck	Low	15	104.1	(15.06)	103.5	(10.50)	n.s.	-0,5
			High	16	114.6	(13.73)	115.1	(12.73)	n.s.	0.04
Working Memory	*Forward*	Met-Fbck	Low	15	3.9	(1.03)	4.1	(1.10)	n.s.	0.12
			High	18	4.9	(1.08)	5.1	(1.75)	n.s.	0.19
		Nor-Fbck	Low	15	3.1	(0.74)	4.1	(1.25)	9.84**	**0.90**
			High	16	4.5	(1.10)	4.6	(0.89)	n.s.	0.06
	Backwards	Met-Fbck	Low	15	1.3	(1.03)	2.0	(1.13)	6.68*	**0.64**
			High	18	3.0	(0.91)	2.9	(1.00)	n.s.	*-0,05*
		Nor-Fbck	Low	15	1.4	(1.24)	1.8	(1.42)	n.s.	*0.32*
			High	16	2.5	(1.37)	2.6	(1.09)	n.s.	0.05
Simon Says	*% Inhibition Error*	Met-Fbck	Low	10	34.0	(21.18)	24.0	(26.3)	n.s.	0.31
			High	11	22.7	(14.89)	13.6	(8.09)	n.s.	0.28
		Nor-Fbck	Low	15	40.0	(20.4)	22.5	(17.12)	8.25**	**0.54**
			High	12	24.5	(17.53)	17.3	(12.72	n.s.	0.22

Table 4.2.3. Mean and Standard Deviation (SD) of the Pre and Post test scores for all the Pen and Pencil assessment tests split by pre-test performance. Planned contrast indicates the f value for the significant comparisons between pre and post-test scores.

4.4.3.1 K-BIT

Results for the Matrices scale shows a significant main effect of Performance Level ($F(1,89) = 6.48$, $p < .05$, $\eta^2_p = 0.06$) indicating that the Low-performance ($M = 101.57$, $SD = 11.13$) has a significantly lower score than the High-Performance sub-group ($M = 118.32$, $SD = 12.18$). Also a main effect of Session ($F(1,89) = 9.55$, $p < .01$, $\eta^2_p = 0.09$) and a significant Session x Group interaction ($F(1,89) = 4.65$, $p < .05$, $\eta^2_p = 0.09$) were found. Subsequent planned contrasts revealed that the increase in matrices score was significant for the Low-Performance ($F(1,89) = 6.33$, $p < .05$) and High-Performance ($F(1,89)= 6.73$, $p < .05$) MF sub-groups, whereas for NF results show a significant effect for the Low-Performance sub-group ($F(1,89) = 4.80$, $p < .05$). For the AC group results where non significant for either of the subgroups, but we see decrease in the post-test score for the High-Performance level, perhaps indicating a return to the mean effect (see figure 4.2.3).

Results for the Vocabulary Scale shows a significant main effect of Performance Level ($F(1,89) = 34.60$, $p < .001$, $\eta^2_p = .27$) indicating that the Low Performance sub-group ($M = 100.90$, $SD = 15.40$) has a significantly lower score than the High Performance sub-group ($M = 116.22$, $SD = 13.90$). Planned contrasts revealed that the increase in vocabulary scores was marginal for the Low-Performance MF group ($F(1,89) = 3.11$, $p = .08$), and not significant for the High-Performance MF, low-performance NF, High-performance NF (all F´s < 1).

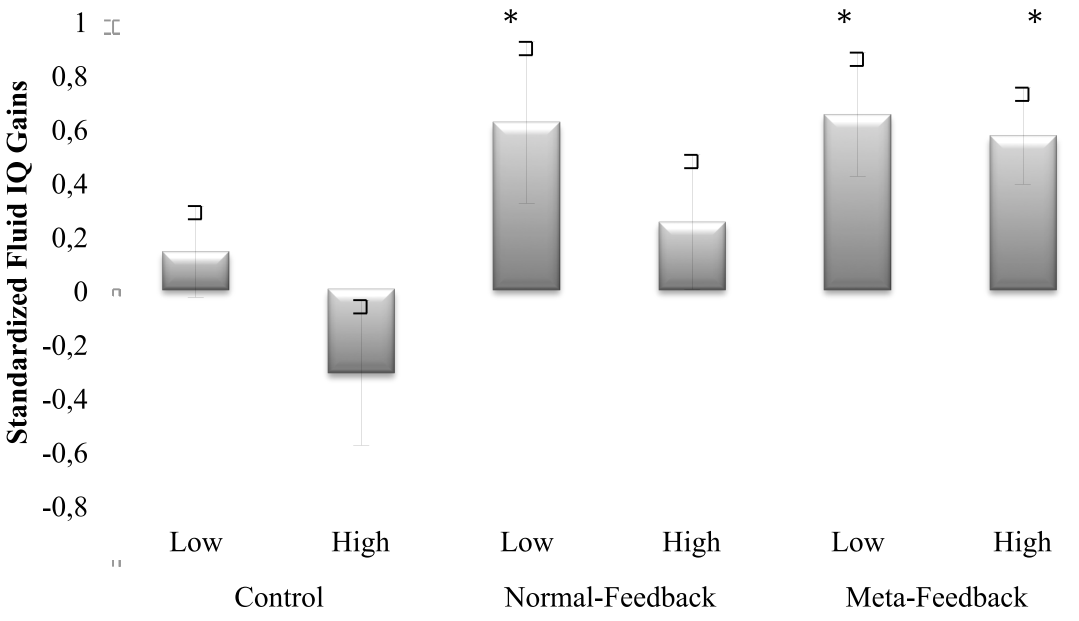


Figure 4.2.3. Standardized fluid IQ scores are presented for pre-test low and high performance sub-groups. Graphics show that training helps to improve low performance group despite training strategy, however only MF group show a significant improvement for the high-performance group.

4.4.3.2 Simon Says

Results for the Simon Says task shows a significant main effect of Performance Level (F(1,55) = 216.36, $p < .001$, $\eta^2_p = 0.22$) indicating that the Low performance sub-group (M = 36.83, SD = 18.77) committed significantly more errors than the High Performance sub-group (M = 21.05, SD = 16.54). Also a significant main effect of Session (F(1,55) = 16.05, $p < .001$, $\eta^2_p = 0.22$), and a significant Session x Performance Level interaction (F(1,55) = 35.07, $p < .05$, $\eta^2_p =$ 0.08). Planned contrasts show a significant reduction of errors between pre and post training sessions for the Low Performance MF group (F(1,55) = 4.79, $p < .05$) and for the Low-Performance NF group (F(1,55) = 11.65, $p < .01$).

4.4.3.3 Working Memory.

Results for the Direct scale shows a significant main effect of Performance Level (F(1,89) = 20.03, p < .001, η2p = 0.18) indicating that the Low-Performance sub-group (M = 3.78, SD = 1.08) has a significantly lower score than the High-Performance sub-group (M = 4.63, SD = 1.03), and a significant main effect of Session (F(1,89) = 6.41, p < .05, η2p = .06). Subsequent planned contrasts revealed that the training effect was significant for the Low-Performance sub-group of the NF Group (F(1,89) = 9.84, p < .01), while for the High-Performance NF, Low and High Performance MF, and High and Low Performance AC no significant result was obtained (all F´s <1).

Results for the Backwards scale shows a significant main effect of Performance Level (F(1,89) = 18.47, p < .001, η2p = 0.17) indicating that the Low-Performance sub-group (M = 1.38, SD = 1.11) has a significantly lower score than the High-Performance sub-group (M = 2.79, SD = 1.19) and a significant main effect of Session (F(1,89) = 3.80, p < .05, η2p = 0.04). Planned contrast revealed that the training effect was significant for the Low-Performance MF Group (F(1,89) = 6.68, p < .01). Non significant results were found for the High-Performance MF (F < 1), Low-Performance (F(1,89) = 2.57, p = .11) and High-Performance (F < 1) NF group, and for the Low and High-Performance AC group (both F´s < 1).

4.4.5 Discussion

The present study aimed to further examine near and far-transfer effects of an attention-training program, and to determine whether it is possible to boost transfer effects by including a metacognitive intervention. Accordingly, results show near-transfer effect indicated by a decrease of inhibitory control errors, and a far-transfer effect to scores related to *Gf*.

As expected, we found that the attention-training program improves measures of inhibitory control by showing a decrease in inhibition errors after training. Our results shows that the improvement in inhibitory control its similar for MF and NF groups indicating that training intervention may improve processes that are related to the cognitive control regardless of training strategy. However, we did not find evidence of far-transfer effects into measures of working memory. Thorell et. al. (2009) conducted a study where they compared near and far-transfer effects between a working memory training and a inhibitory control training. In this study, the data show no evidence of far-transfer effect of inhibitory control training into measures of working memory. Authors suggested that it is possible that the lack of transfer effects may be related to the relativebly different underlying brain structures that supports each process (Baddeley, 2003; Munakata et al., 2011), which may help us to interpreted the lack of far-transfer effects into WM in our study. It may also be possible that the lack of transfer effects may be due to the low variability in our measures of WM, specially in the most demading condition of backwards where the engagement of executive control its more important.

Consistent with previous studies we found that training into cognitive control processes results in improvement of *Gf* scores (Bergman et al., 2011; Jaeggi et al., 2008; Rueda et al., 2012; Rueda, Rothbart, et al., 2005). Neuroimaging studies have provided evidence that suggests that processes measured by intelligence test activate a series of common regions that are also engage by to executive control (Duncan & Owen, 2000; Hampshire et al., 2010, 2012). This evidence suggests that far-transfer effects are possible when there are a group of shared underlying brain structures of the processes triggered by trained and assessment tasks (Rueda et al., 2012; Rueda, Rothbart, et al., 2005).

Another possible explanation can be drawn from the hierarchical model of G (Demetriou et al., 2008). From this theoretical perspective it is possible that cognitive training improves lower-level perceptual control processes, which in turn improves the efficiency of processes at higher hierarchical levels (i.e. working memory, information integration and reasoning). Several studies supports this explanation showing that the relation between processes embedded in the higher hierarchical level (i.e. representational processes level) and the G index, are mediated by processes related to control of interference attributed to executive attention (Demetriou et al., 2008; Engle et al., 1999; Unsworth & Engle, 2005).

Also, our results shows that the metacognitive intervention produces different impact on Gf, even when no differential effects where found on inhibitory control measures. We found that MF training produced higher increase of Gf scores in comparison with NF training. These results may indicate that while attention training its targeting lower-level perceptual control processes, the metacognitive training may be influencing higher-level representational processes. In the present study, MF training was intended to provide a scaffolding to improve children´s ability to extract task relevant information and to integrate it into a model that would allow them to implement strategies to improve their performance, thus engaging higher-level representational processes into training.

In order to better characterised the impact of training in relation to individual differences we divided the training groups into high and low performance based on the pre-training scores. Consistent with Jaeggi et al. (2011) our results shows an improvement of *Gf* scores and inhibitory control measures in the low performance group regardless of the training strategy, which may indicate that attention-training benefits children that starts with lower abilities because they have more room for improvement. However we find that only children in the high performance MF group improve on *Gf* scores. This data provides evidence showing that even when children shows an already high age-related level of efficiency in reasoning abilities, this development can be boosted when its supported by proper scaffolding. Considering this results from the hierarchical structural model of *G* (Demetriou et al., 2008), this data suggests that both low-performance MF and NF would increase in *Gf* scores because attention-training improves efficiency of lower level perceptual control processes to the same extent, however only the High performance MF group would increase in *Gf* scores because the metacognitive scaffolding encourage children to engage higher level reasoning processes to improve their performance, which may lead to an enhancement of the efficiency of this hierarchical-level processes.

The present study intended to provide further evidence of the beneficial effects of cognitive training in pre-school children. Our results provides evidence that indicates the importance of considering the implementation of carefully design educational strategy together with cognitive training programs in order to enhance the beneficial effects of such interventions. Also, it provides evidence that indicates the beneficial influence of the ZPD in children´s development of cognitive control mechanisms. In line with the vygotskian perspective (Bodrova et al., 2011; Luria, 2002; Vygotsky, 1978a), our data show that children´s cognitive development its boosted when its supported by the proper scaffolding from more experience peers or adults. The enhancement of far-transfer effects by the metacognitive training provides empirical evidence that shows how children are benefited from a carefully designed scaffolding intervention. Finally, the study of the effects of training interventions may be a suitable method for further research the interplay between cognitive control processes, social-interaction, language and reasoning abilities.

4.3 Metacognitive training improves electrophysiological markers of conflict monitoring in young children.

4.3.1 Introduction

Voluntary regulation of thoughts and feelings is an important ability that relies on the interplay of different cognitive processes which are often referred to as cognitive control mechanisms (Ochsner & Gross, 2005; Posner & Rothbart, 1998; Rueda, Posner, et al., 2005). Within the general domain of cognitive control, attention has been described as a basic set of processes that underlie the individual´s ability to monitor information processing. This allows the detection of possible sources of conflict in order to resolve them, ranging from immediate detection of mistakes to the change of habitual behavioural patterns according to circumstances. (Norman & Shallice, 1986; Posner et al., 2007b). A current neurocognitive model of attention characterizes these processes as being part of the executive attention network, which is related to the Anterior Cingulate Cortex (ACC) and prefrontal brain regions (Petersen & Posner, 2012; Posner & Petersen, 1990).

Processes related to the executive attention network are often assessed by the flanker task, a test that induces conflict between responses evoked by different stimuli dimensions (Eriksen & Eriksen, 1974). In detail the flanker task elicits perceptual conflict by manipulating the direction of the flanker arrows that surround the central target arrow. Behavioural studies show that when flanking arrows point to a different direction than the central target arrow (the incongruent condition) participants are less accurate and respond slower than in the congruent condition, when all arrows point to the same direction. This delayed response suggests an involuntary processing of irrelevant flanker information. In order to correctly perform the task, participant must be able to detect and inhibit the conflicting information produced by the incongruent flanker stimuli. Electrophysiological studies with adults have associated conflict-monitoring processes to the N2 event-related potential (Also called N450; Abundis-Gutiérrez, Checa, Castellanos, & Rosario Rueda, 2014; Liotti, Woldorff, Perez, & Mayberg, 2000; Szűcs & Soltész, 2012), which has been characterized as a pre-response negative deflection that occurs around 200 to 450 ms after stimuli-onset with a fronto-central distribution, and presents higher negative amplitude for incongruent compared to congruent trials (Clayson & Larson, 2013; Folstein & Van Petten, 2008; Mansfield et al., 2013; Veen & Carter, 2001). Source localization studies have suggested the ACC as the possible generator of the N2 component (Carter & van Veen, 2007; Veen & Carter, 2001).

Developmental studies suggest that the executive attention networks have a protracted developmental trajectory with the strongest changes observed during early childhood (Davidson et al., 2006b; Rueda, Posner, et al., 2004; Rueda, 2014; Rueda, Fan, et al., 2004). Data from these studies suggest that younger children are less effective than older children in performance on tasks that induce conflict. Specifically, behavioural studies using the flanker task have shown a steady reduction of conflict scores between the age of 2 and 7 years with a subsequent stability up to adulthood, suggesting that younger children have more difficulty in monitoring and resolving conflict from competing stimulations compared to older children and adults (Pozuelos, Paz-Alonso, Castillo, Fuentes, & Rueda, 2014; Rothbart, Ellis, Rosario Rueda, & Posner, 2003; Rueda, Fan, et al., 2004).

Studies using electroencephalography (EEG) have reported that brain activity related to conflict monitoring changes with age. Similar to adults, children´s ERPs (N450) show larger negative amplitudes in trials that involve conflict. However this conflict related negative modulation was found larger in amplitude, extends longer and showed a more anterior scalp distribution than that of adults (Abundis-Gutiérrez et al., 2014; Purificación Checa et al., 2014; Rueda, Posner, et al., 2004). Moreover, developmental studies have shown that these N450 effects decrease in amplitude with age suggesting that the efficiency of the executive attention network improves with age (Abundis-Gutiérrez et al., 2014; Lisa M Jonkman, 2006; Lamm et al., 2006).

Self-regulation abilities are important for succeeding in life. From early childhood on individuals are faced with many situations that require an adequate control of cognition, emotion and behaviour, which underscores that the emergence of cognitive control mechanisms is a central aspect in children’s development. Several studies have shown that children with greater executive attention efficiency (i.e. smaller conflict scores) perform better in school and exhibit better socio-emotional adjustment in the classroom (Blair & Razza, 2007; Purificación Checa, 2010; Rueda et al., 2010). In a recent study, Checa and Rueda (2011) showed that brain activation related to conflict monitoring predicted childrens math grades better than general intelligence measures. It has been also suggested that higher levels of attention and effortful control are regarded as characteristics that may prevent the development of different psychopathologies, such as ADHD (Halperin, Bédard, & Curchack-Lichtin, 2012; Melby-Lervåg & Hulme, 2013; Rueda, Posner, et al., 2005). Therefore, it is important to address the potential benefit of cognitive and educational interventions regarding the emergence of attention regulation abilities.

In the past decade the number of studies on the benefit of cognitive training has exponentially grown. Cognitive training can be defined as a process of improving cognitive abilities by means of practice (Jolles & Crone, 2012). Neuroimaging studies show the effectiveness of cognitive training to influence brain plasticity that underlies observed behavioural benefits. Several studies have demonstrated the beneficial effects of cognitive training in behavioural and neurocognitive measures of working memory (Martin Buschkuehl, Jaeggi, & Jonides, 2012; Klingberg, 2006; Olesen et al., 2004), intelligence (Bergman et al., 2011; Jaeggi et al., 2008; Rueda, Rothbart, et al., 2005) and cognitive flexibility (Karbach & Schubert, 2013; Minear & Shah, 2008).

The combined evaluation of behavioural as well as event-related potential measures to study the influence of attention training programs in pre-school aged children needs to be further investigated (Rueda et al., 2012; Rueda, Rothbart, et al., 2005). Rueda et al. (2005) showed that attention-training influences behavioural measures and produces a far-transfer effect that manifests as an increase in fluid intelligence scores after training. Moreover, their results indicated that training-related effects on ERP components were similar to the influence of development. The 4-year-old trained group exhibited more negative amplitudes for incongruent trials in the time-window of the N450 component that are comparable to the untrained group of 6-year-old children. The topography of the trained group of 6-year-old children already resembles that of the adult population however with a more dorsal-frontal distribution. Taken together, these experiments demonstrated that attention training produces a near transfer effect that helps to complement that of normal development in a way that may promote a faster maturation of the underlying brain structures. In a follow up study Rueda et. al. (2012) showed that attention-training produces an increase in fluid-IQ scores and influence the latency and topographical distribution of the N450 ERP component. Moreover, the training related changes were found maintained two months after the last training displaying larger negative amplitudes, faster latencies and a more posterior signal distribution.

Computerized training exercises have recently received enhanced attention as they benefit cognitive control processes. However it is still unclear which neural components might benefit from training interventions. One candidate component is metacognition. Metacognition has been defined as the knowledge, affective experience and/or cognitive activity that monitor, evaluate and control one´s own cognitive processes (Efklides, 2008; Flavell, 1979; T. O. Nelson & Narens, 1994). As such the definition of Metacognition is rather coarse and describes metacognitive abilities in terms of control processes and knowledge about our own mental world. It has been suggested that Metacognitive Control (MC) is an analogous system to that of executive attention, due to the fact that both are related to similar control mechanisms and underlying brain structures (Fernandez-duque et al., 2000b; Shimamura, 2008). On the other hand, Metacognitive knowledge (MK) is a complementary system that relies on the individual’s ability to use procedural, declarative and conditional knowledge to create a metacognitive model of ones own cognition, which enables a more efficient implementation of control processes

(Schraw & Moshman, 1995). Efklides (2008) suggested that MK development and improvement is strongly supported by language and social interaction.

In the present study we integrate metacognition into our cognitive training program. We developed a metacognitive scaffolding script based on the principles of Vygotsky´s Zone of Proximal Development (Vygotsky, 1978a, 1997) that was implemented during training sessions as an interactive feedback dialogue. The aim of the feedback dialogue was to provide children with instructions that would enable them to extract necessary information of task features in order to improve their metacognitive knowledge. Through this interactive relationship between trainer and trainee, we evaluated its potential benefit on behavioural and neurocognitive indexes.

4.3.2 Method

4.3.2.1. Subjects

From the total sample of 107 children, 10 children were discarded because they dropped out of the study and 24 did not complete the task either in the pre or the post training evaluation period. Thus data from 73 pre-school children (41 males; mean age: 64.2 months; SD: 6.9 months) was used for further analysis (see table 4.3.1).

		Gender		*Mean Age*	*Mean IQ*
Group	*N*	*Girls*	*Boys*	*(SD)*	*(SD)*
Control	28	11	17	64.4 (6.6)	104 (14.8)
Met-Fbck	25	11	14	63.9 (7.8)	105 (11.7)
Nor-Fbck	20	9	11	64.4 (6.6)	105 (12.5)

Table 4.3.1. Descriptive statistics for the sample.

4.3.2.2 Procedures

A high-density (128-channels) EEG system was used to register children's brain activation while they were completing a child friendly Flanker tasks. An experimenter was present with the children throughout the session in the testing room. Children received plastic coins at the end of each block according to their balance of correct trials. At the end of the session children selected toys and school supplies in exchange for the plastic coins as a gift for their participation in the study. Experimental sessions took place at the Cognitive Neuroscience laboratory of the University of Granada. An experimenter blind to children's experimental assignment guided all pre- and post-training assays, and a different experimenter administered training.

4.3.2.3 Task and measures

4.3.2.3.1. Robots Flanker Task.

The task we used to assess conflict resolution was a child-friendly version of the flanker task designed by our group and was used as in previous studies (Purificación Checa et al., 2014). At the beginning of each trial a fixation cross was displayed at the centre of the screen for a variable duration randomly selected between 600 to 1200 ms. The target stimuli consisted in a row of five cartoon robots presented at the centre of the screen either above or below the fixation cross. Participants were asked to indicate the shape of the robot in the middle (either round or square) by pressing a corresponding button. Flanking robots could be of the same (congruent) or different (incongruent) shape as that of the robot in the middle. The task consisted on a total of 144 trials divided into six blocks. Flanking robots were congruent in half of the trials and the congruency condition was randomly selected for each trial. The response was measured during presentation of the target or up to 800 ms after the target had disappeared. In order to control the difficulty of the task, the target presentation time was adjusted in each trial according to children's performance in the previous trial. When an error was made or the response was given off time, the target duration was increased by 50 ms in the following trial. Alternatively, the target duration in trial n+1 was decreased by 50 ms when the response in trial n was correct. Following the response, a 600 ms-lasting feedback was provided. The feedback consisted of a visual animation of the central figure plus an auditory word ("yes" for correct response, "no" for incorrect response, and "late" for omission or off-time responses). A schematic representation of the experimental task is presented in figure 4.3.1

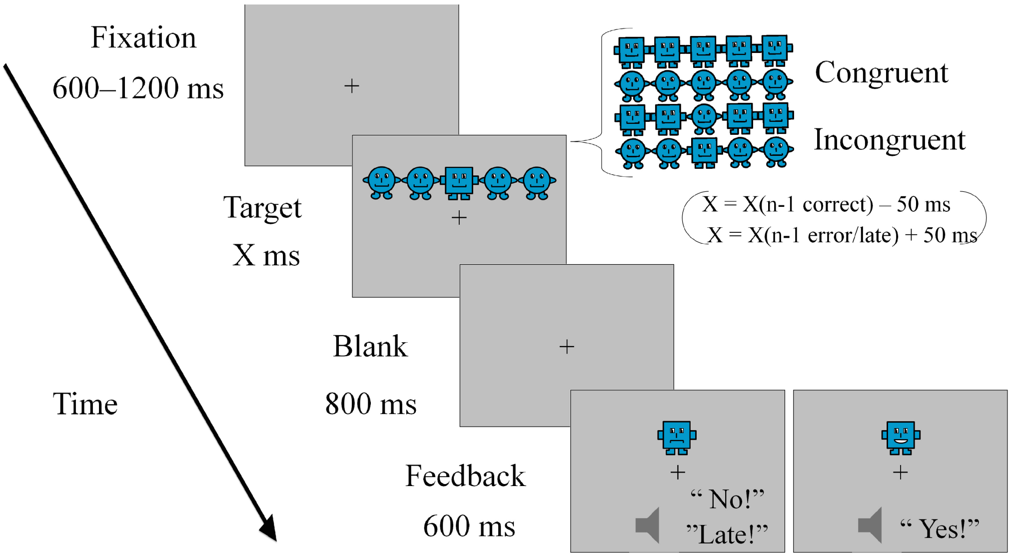


Figure 4.3.1. Schematic representation of the Flanker task.

4.3.2.4. EEG recording and data processing

EEG was recorded using a 128-channel Geodesic Sensor Net 4.2 (EGI Software: www.egi.com). The EEG signal was acquired using a 100 to 0.01Hz band pass filter and digitized at 250Hz. Impedance for all channels was kept below 50KΩ. Pre-processing of continuous data was performed in EEGLAB version 13.2.2 (Delorme and Makeig, 2004). EEG data were filtered using a finite impulse response (FIR) band pass filter with 0.3 Hz high-pass and 30 Hz low-pass cutoffs (Passband gain: 99.0% (-0.1 dB), stopband gain: 1.0% (-40.0 dB), rolloff: 0.29 Hz). After filtering the data, the Fully Automated Statistical Thresholding for EEG artifact Rejection procedure (FASTER, Nolan et al., 2010) was employed for removing artifacts from the data. Using a predefined z-score threshold of ±3 for each parameter, artifacts were detected and corrected regarding single channels, epochs, independent components (based on the infomax algorithm, Bell and Sejnowski, 1995) and single-channel single-epochs. Remaining artifactual independent components and epochs containing artifacts were removed after visual inspection.

After artifact removal, the event related potentials (ERP) were processed using the ERPLAb toolbox (Lopez-Calderon & Luck, 2014). Continuous data were segmented into target-locked epochs of 1200 ms long (-200 to 1000 ms) with a pre-stimulus baseline correction of 200ms. Artifact-free segments were averaged across conditions and participants within each training group, and re-referenced to the average of all channels. A per-subject criterion of a minimum of 15 artifact-free segments per experimental condition was established in order to be included in the grand-average for each age group. A total of sixty-nine children reached that criterion, 26 from the Control group, 23 for the Metacognitive-feedback Group and 20 from the normal-feedback group.

4.3.3. Results

In order to assess the specific effects of the attention training program we first examined the electrical activity in the Pre-training session to confirm that the ERPs are in line with the patterns observed in previous studies using a similar flanker tasks (Abundis-Gutiérrez et al., 2014; Purificación Checa et al., 2014; Rueda, Posner, et al., 2004).

Data analysis was carried out using two different strategies. First, to examine the effects of the task condition and training influences on the ERPs components we conducted a series of ANOVAs in order to detect differences related to stimuli manipulation and training intervention. Second, we conducted a series of Pearson´s correlations in order to investigate the relation between ERP components modulation and behavioral data (i.e. reaction time (RT), accuracy and intelligence).

4.3.3.1 Target-Locked ERPs for pre training session

4.3.3.1.1. Target-Locked ERPs

The amplitude difference between congruent and incongruent trials appeared to be largest between 450-950 ms post-target (N450). To analyze the congruency effect, the mean amplitude per condition and the negative area of the difference wave-form was calculated for the time window of 450 – 950 ms. Data from three different clustered electrode sites which corresponds to anterior, middle and posterior lead positions were included in the analysis. Averaged ERPs per Flanker Type, electrode site and topographical distribution are presented in figure 4.3.2.

A 2 (Flanker Type) x 3 (electrode site: anterior, middle and posterior) repeated measures ANOVA was run with the mean amplitude as dependent measure. Results showed a significant main effect of electrode site (F(2,136) = 66.57, p < .001) indicating higher mean amplitude (measure in µ volts units) for the posterior site (M = 3.38, SD = 3.59) as compared to the middle (M = 0.78, SD = 4.45) and the anterior sites (M = -0.98, SD = 4.92). There was also a main effect of Flanker Type (F(1,68) = 5.72, p < .05) indicating that the amplitude was more negative for the incongruent (M = 0.72, SD = 4.45) as compared to the congruent condition (M = 1.40, SD = 5.12). There was no significant Position x Flanker Type interaction (F < 1).

To further analyze our data, we used the difference waveform area as dependent measure and conducted a one-way ANOVA with electrode site (anterior, middle and posterior) as independent variable. Results showed a significant main effect of Position (F(2,136) = 6.44, p < .01). Subsequent planned contrasts showed a significant difference between anterior and middle site (F(1,68) = 6.64, p < .05) and anterior and posterior sites (F(1,68) = 7.73, p < .01) (See Figure 4.3.2).

4.3.3.1.2 Correlations between Target-Locked ERPs and behavioural measures.

Pearson´s correlations were calculated to assess the relation between ERPs and behavioural measures. We calculated conflict ERP indexes (N450) by subtracting the mean amplitude for congruent trials from the mean amplitude for incongruent trials at each electrode site and used it together with the difference in waveform area as electrophysiological measures. Behavioural measures included conflict scores of flanker interference (i.e. RT and accuracy) and scores of the verbal IQ, fluid IQ and total IQ scales of the K-Bit intelligence test were used as behavioural measures (See table 4.3.2.).

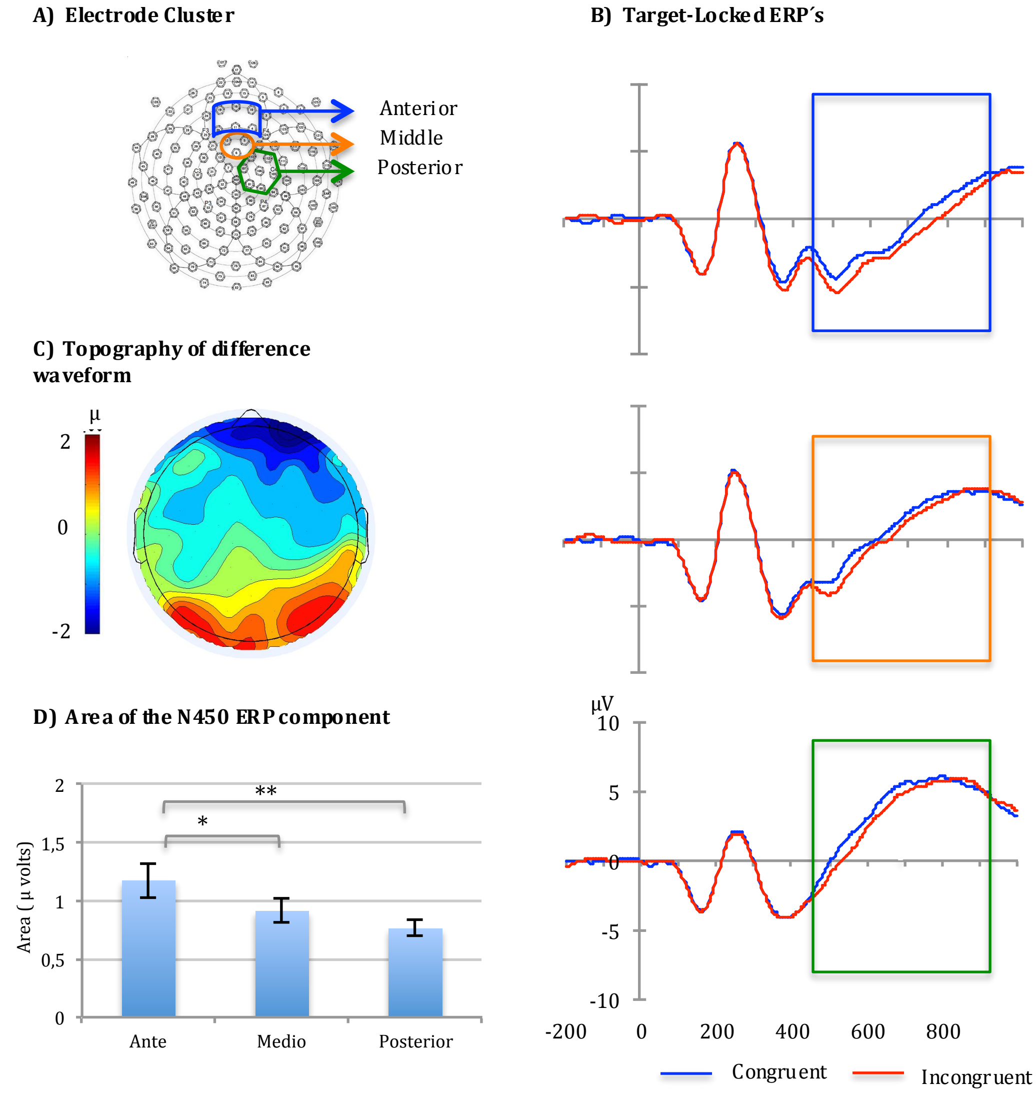


Figure 4.3.2. A) Electrode clusters sites, **B)** Response-Locked ERP´s for the N450 representing congruent and incongruent waveforms, **C)** Topographical distribution and **D)** Area of the difference waveform at each electrode site.

Results showed a significant positive correlation between mean amplitude differences and conflict ACC scores at anterior (r = .266, p < .05), and middle (r = .303, p < .05) electrode site. Also, we found a significant negative correlation between area at anterior electrode site with conflict ACC scores (r = -.257, p < .05).

				1	2	3	4	5	6	7	8	9	10	11
	IQ Scores	1	Total-IQ	-										
		2	Fluid-IQ	.79	-									
		3	Verbal-IQ	.88	**.46**	-								
	Conflict effects	4	RT´s	-.25	-	-	-							
		5	% Errors	-	**-.28**	**-.25**	-	-						
ERP´s Measures	**Anterior**	6	Area	-	-	-	-	**-.25**	-					
		7	Conflict	-	-	-	-	**.26**	**-.96**	-				
	Middle	8	Area	-	-	-	-	-	**.73**	**-.74**	-			
		9	Conflict	-	-	-	-	**-.30**	**-.66**	**.73**	**-.92**	-		
	Posterior	10	Area	-	-	-	-	-	-	-	**.46**	**-.38**	-	
		11	Conflict	-	-	-	-	-	-	-	**-.37**	**.36**	**-.93**	-

Table 4.3.2. Statistically significant correlations among behavioural measures of Intelligence and performance on the flanker task as well as electrophysiological measures of area of the difference waveform and conflict (mean amplitude incongruent – mean amplitude congruent) at pre-training test session.

4.3.4. Discussion of Pre-training ERPs

Replicating previous studies (Abundis-Gutiérrez et al., 2014; Purificación Checa et al., 2014; Rueda, Posner, et al., 2004) our results from the pre-training session revealed that manipulation of the flanker congruency modulated the amplitude of the target-locked N450 potential. Using the same task, Checa et. al. (2014) reported that flanker congruency produced a sustained negative deflection that peaks around 500 ms after stimuli onset, it is larger in amplitude for the incongruent compared to the congruent condition and presents a more frontal distribution. Accordingly, convergence of data from mean amplitude and area measures suggested an increased modulation of conflict-related ERPs at frontal electrode sites.

Previous studies have shown that the manipulation of congruence between relevant and distracting information modulates the amplitude of the N2 component in adults (Botvinick et al., 2001; Kanske & Kotz, 2010; Mansfield et al., 2013; Rueda, Posner, et al., 2004; Veen & Carter, 2001), however this effect appears to vary with age. Several studies have shown that younger children appeared to have larger conflict effects in the N2/N450 amplitude compared with older children and adults, and that this difference decreased with age (Hämmerer, Li, Müller, & Lindenberger, 2010; Ladouceur, Dahl, & Carter, 2007; Lamm et al., 2006). It has been suggested that these age-related differences in the amplitude of the N2/N450 component are related to a poorer functional efficiency of the executive attention network in children (Purificación Checa et al., 2014).

Our results indicate that the mean amplitude and the area of the N450 component are functionally related to behavioural measures. Our findings showed that the smallest N450 mean amplitude conflicts at anterior and middle sites are related to highest conflict ACC scores. Furthermore we found a negative correlation between the area and the conflict ACC score at anterior sites. In contrast to previous studies (Abundis-Gutiérrez et al., 2014; Purificación Checa et al., 2014; Hämmerer et al., 2010; Lamm et al., 2006; Rueda, Posner, et al., 2004) our data suggested that the smaller the conflict mean amplitude of the N450 the poorer the effectiveness of the executive attention network. It has been proposed that the lack of attention to the task induces smaller amplitudes in ERP components and higher error rates (Schooler et al., 2011; Smallwood, Beach, Schooler, & Handy, 2008), and therefore the relation between smaller N450 amplitude and larger conflict ACC scores may be due to children´s inability to sustain engagement to the task.

After having characterized ERP components that are modulated by stimuli presentation we conducted a series of analysis to evaluate the influence of attention training in brain activity following the same strategy used for the Pre-training data.

4.3.4 Cognitive training influence on behavioural and electrophysiological measures

4.3.4.1 Behavioural Results

Reaction time and accuracy data for each training group are presented in table 4.3.3. To be included in the analyses, participants must not have a percentage of errors exceeding 2 SD of the mean of its particular age group. However, no one of the children participating met the exclusion criterion. We conducted separate 2 Session (Pre, Post) x 2 Congruency (Congruent, Incongruent) x 3 Training Group repeated measure ANOVA with RTs and percentage of errors as dependent measures to evaluate the influence of attention training in conflict resolution.

For RT, our results revealed a significant main effect of session (F(1,70) = 20.81, p < .001) indicating a decrease in RTs in the post (M = 781, SD =

190) compared to the pre-training session (M = 846, SD = 176). We also found a significant main effect of congruency (F(1,70) = 53.14, p < .001) indicating that RTs were faster for the congruent condition (M = 793, SD = 190) compared to the incongruent condition (M = 838, SD = 194). Finally a significant session x congruency interaction was found (F(1,70) = 7.92, p < .01), indicating a higher reduction of RT for the incongruent condition (76 ms) compared to the reduction in the congruent condition (49 ms).

For percentage of errors, our results revealed a significant main effect of session (F(1,70) = 20.12, p < .001) indicating a increase in errors in the post session (M = 33.13, SD = 9.02) compared to the pre session (M = 28.69, SD = 7.79). We also found a significant main effect of congruency (F(1,70) = 91.93, p < .001) indicating that less errors were committed for the congruent condition (M = 26.98, SD = 9.03) compared to the incongruent condition (M = 36.66, SD = 8.65).

4.3.4.2 Conflict Scores

Conflict scores for RTs and percentage of errors are presented in table #. Conflict scores were calculated by subtracting the median RT for trials with congruent flankers from the median RT for trials with incongruent flankers. The same formula was used to compute conflict scores for percentage of errors.

Differences between groups on conflict scores were analysed by means of one-way ANOVAs using training group as factor.

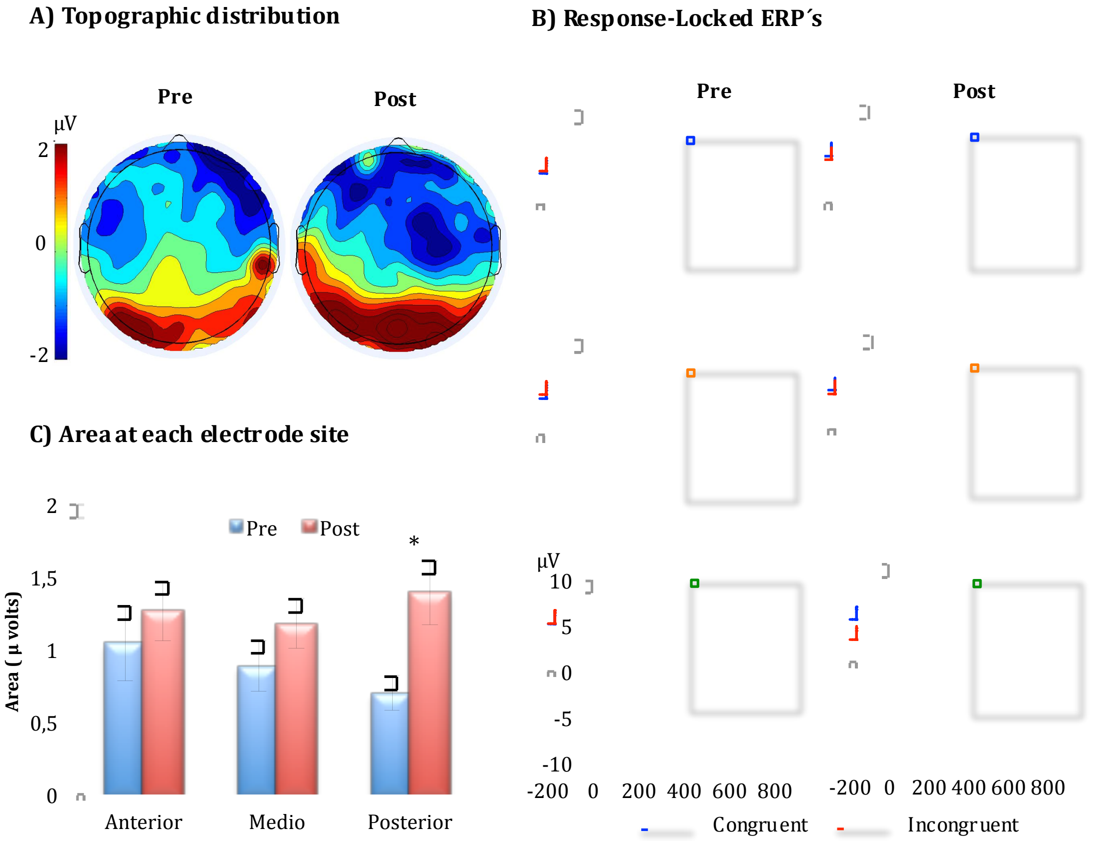
Results for RTs revealed a significant main effect of session (F(1,70) = 7.75, p < .01) indicating higher conflict scores in the pre (M = 58.60, SD = 76.30) compared to the post (M = 31, SD = 52.73) training session. The main effect of group and the Session x group interaction were not significant (all F´s < 1). Results of the ANOVA with conflict scores for percentage of errors did not show any significant main effect or interactions.

		Pre		*Post*	
Group	***DV***	***RT***	***Accuracy***	***RT***	***Accuracy***
Met-Fbck	Overall	834 (170)	28.6 (7.9)	774 (183)	32.2 (8.9)
	Congruent	814 (160)	24.9 (9.2)	765 (192)	29.1 (10.4)
	Incongruent	864 (186)	32.2 (9.3)	193 (190)	35.3 (8.4)
	EX_Score	50 (69)	7.2 (9.6)	28 (55)	6.2 (6.0)
Nor-Fbck	Overall	861 (231)	26.7 (7.7)	792 (205)	30.7 (8.4)
	Congruent	830 (207)	22.9 (9.8)	773 (202)	26.1 (10.5)
	Incongruent	891 (261)	30.4 (8.2)	809 (203)	35.2 (8.1)
	EX_Score	61 (96)	7.4 (9.6)	35 (39)	9.1 (8.4)
Control	Overall	843 (141)	30.2 (7.8)	780 (193)	35.7 (9.9)
	Congruent	811 (131)	26.2 (8.4)	768 (188)	32.5 (12.7)
	Incongruent	876 (157)	34.2 (8.6)	798 (198)	38.9 (9.0)
	EX_Score	64 (68)	8.1 (6.9)	31 (60)	6.6 (9.6)

Table 4.3.3. Pre and post-training mean (SD) of RTs and percentage of errors are presented for each group.

4.3.4.3. Training influence on Target-Locked ERPs

Training data was analyze by means of a 2 (Session) x 3 (Position) x 2 (Congruency) repeated measure ANOVA with training group as a between subject factor. Results revealed a significant main effect of position (F(2,132) = 71.28, p < .001) indicating a lower general mean amplitude in anterior (M = -1.38, SD = 5.12) than in middle (M = 0.41, SD = 4.45) and posterior (M = 3.20, SD = 4.45) electrode sites. Results also revealed a significant main effect of congruency (F(1,66) = 9.98, p < .01) indicating higher amplitude for the congruent (M = 1.06, SD = 4.59) compared to the incongruent condition (M = 0.41, SD = 4.45). In order to characterize the influence of training we conducted a series of planned contrasts comparing the amplitude differences of congruent conditions in the pre and post training session within each training group. Results showed that for the MF group in the pre session there were no significant differences between congruency conditions in any of the electrode sites (all F´s < 1), however for the post training session there was a significant difference for the middle (F(1,66) = 3.94, p < .05) and posterior (F(1,66) = 7.60, p < .05) electrode sites (see figure 4.3.3).


A) Topographic distribution

B) Response-Locked ERP´s

C) Area at each electrode site

Figure 4.3.3. Metacognitive Feedback group pre and post-training session. A) Spherical spline interpolated scalp topographies of the difference waveform (incongruent – congruent). Positive values indicate an increase in amplitude; negative values indicate a decrease in amplitudes. B) Grand average of response-locked ERP´s at each electrode site for congruent and incongruent waveforms. C) Area of difference waveform at each electrode site.

For the NF group there were no significant differences between congruency conditions for the pre training session, however there was a marginal effect at posterior electrode sites (F(1,66) = 2.51, p=.10) for the post training session (see Figure 4.3.4).

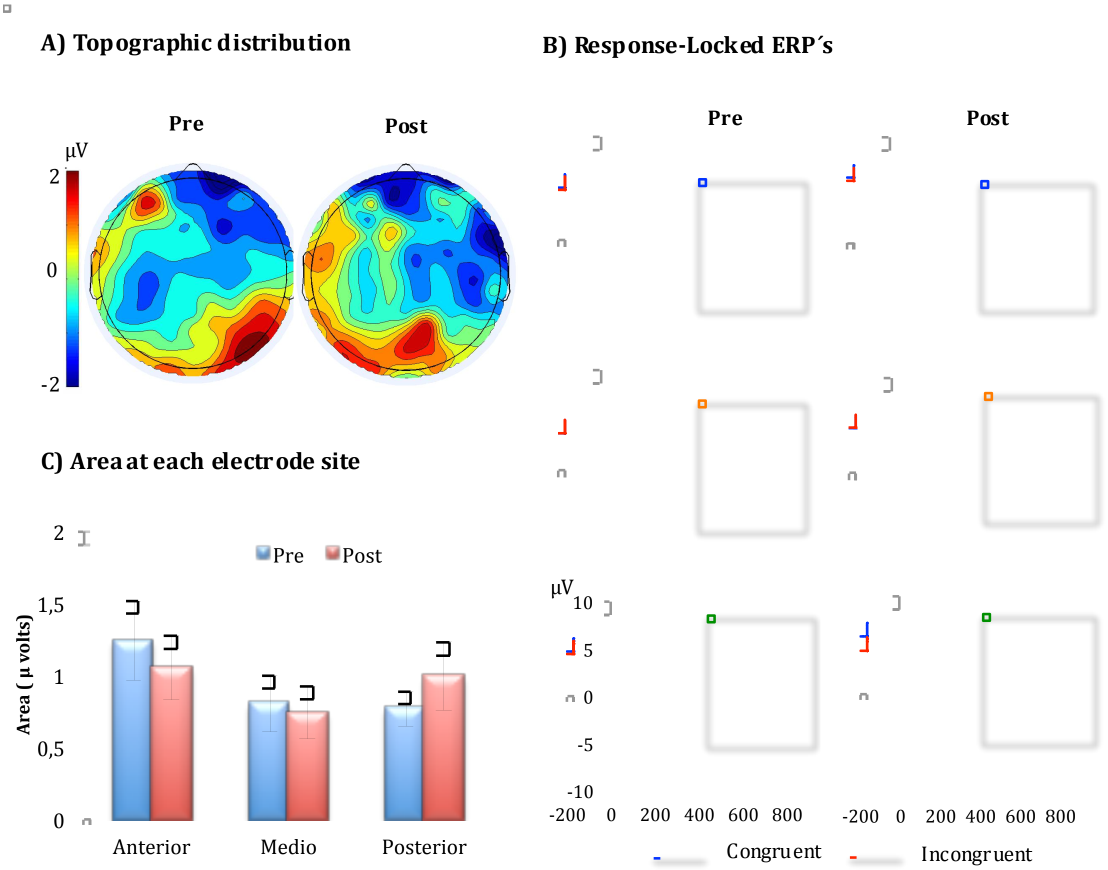


Figure 4.3.4. Normal Feedback group pre and post-training session. A) Spherical spline interpolated scalp topographies of the difference waveform (incongruent – congruent). Positive values indicate an increase in amplitude; negative values indicate a decrease in amplitudes. B) Grand average of response-locked ERP's at each electrode site for congruent and incongruent waveforms. C) Area of difference waveform at each electrode site.

For the AC group the pre training session revealed a significant congruency difference in the posterior (F(1,66) = 4.18, p < .05) and a marginal in the anterior (F(1,66) = 3.24, p = .07) electrode sites, however in the post session no significant congruency difference was found (all F´s < 1) (see Figure 4.3.5).

To assess the influence of training on the difference waveform area we conducted a 2 (session) x 3 (electrode site) repeated measure ANOVA with training group as a between subjects factor. Results revealed a significant main effect of position (F(2,132) = 6.09, p < .01), indicating a general higher area in anterior leads (M = 1.15, SD = 1.23) than in middle (M = 0.91, SD = 0.86) and posterior (M = 0.87, SD = 0.79). Planned contrasts showed that for the MF there was a significant difference in the posterior lead (F(1,66) = 6.26, p < .05) between pre and post training. For the NF as well as for the AC groups there were no significant differences of area between pre and post training in any of the electrode sites..

4.3.4.4. Correlation between Target-Locked ERP´s and behavioural measures

Pearson correlations were calculated to evaluate the functional relation between the changes in ERPs and behavioural measures after training. In order to calculate the correlations we computed a training effect score (post – pre session) for the mean amplitude and area for the difference waveforms and a training effect score for the behavioural measures (i.e. intelligence and conflict scores computed for reaction times, percentage of errors)

Results for the MF revealed that the training effect on mean amplitude difference had a significant negative correlation with training effect for Verbal scale (r = -.511, p < .05), Total IQ scale (r = -.673, p < .01) and was marginally significant with Matrices scale (r = -.419, p = .07) at anterior electrode sites. We also found that the effect of training in area of difference waveform had a significant positive correlation with the training effect for Verbal scale (r = .497, p < .05), Total IQ scale (r = .637, p < .01) and was marginally significant with

Matrices scale (r = .382, p = .10) at anterior electrode sites (see table 4.3.4 and figure 4.3.6).

Results for the NF group revealed no significant correlations between changes in the ERPs and behavioural measures.

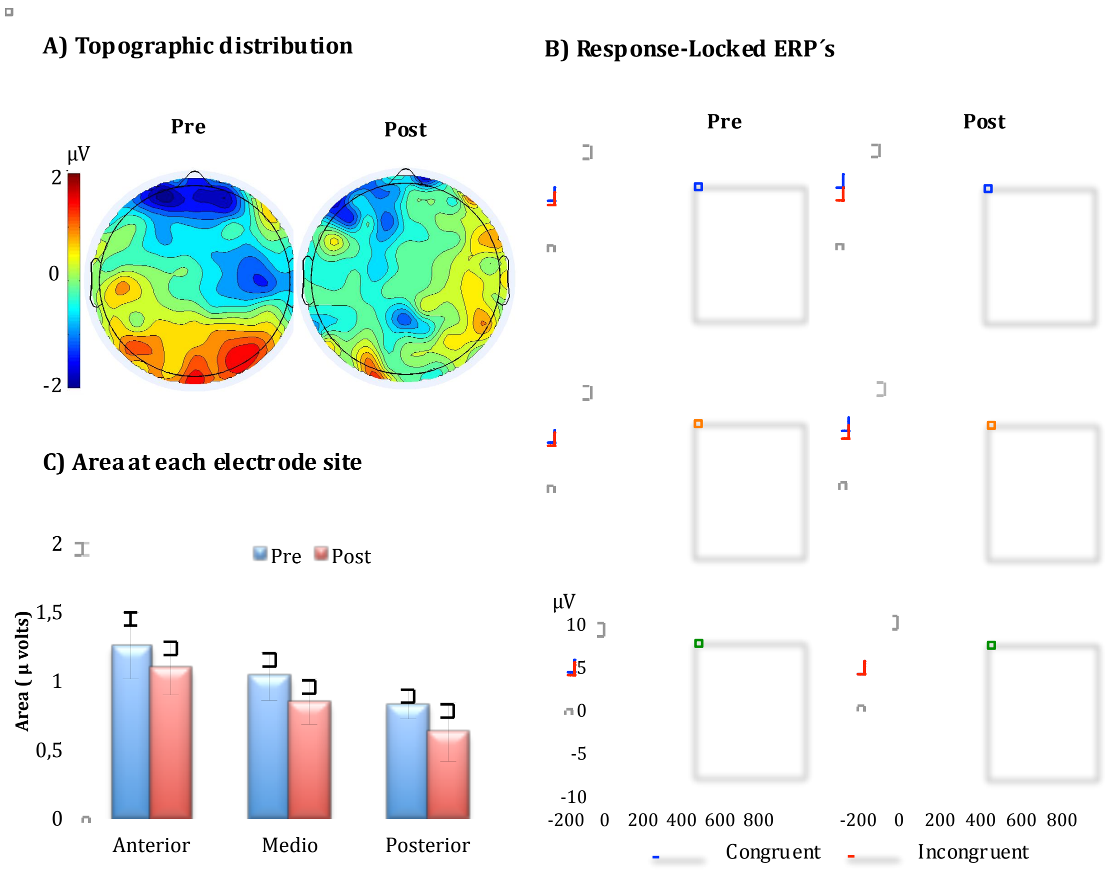


Figure 4.3.5. Active Control group pre and post-training session. A) Spherical spline interpolated scalp topographies of the difference waveform (incongruent – congruent). Positive values indicate an increase in amplitude; negative values indicate a decrease in amplitudes. B) Grand average of response-locked ERP´s at each electrode site for congruent and incongruent waveforms. C) Area of difference waveform at each electrode site.

				1	2	3	4	5	6	7	8	9	10	11
	IQ Gain	1	Total-IQ	-										
		2	Fluid-IQ	.75	-									
		3	Verbal-IQ	.69	-	-								
	Conflict effects Gain	4	RT´s	-	-	-	-							
		5	% Errors	-	-	-	-	-						
ERP´s Measures	**Anterior**	6	Area	.63	-	.49	-	-	-					
		7	Conflict	-.67	-	-.51	-	-	-.88	-				
	Middle	8	Area	-	-	-	-	-	**.70**	-.57	-			
		9	Conflict	-	-	-	-	-	**-.57**	**.75**	-.96	-		
	Posterior	10	Area	-	-	-	-	-	.46	**-.67**	**.80**	-.95	-	
		11	Conflict	-	-	-	-	-	-	-	**-.61**	**.69**	-.95	-

Table 4.3.4. Statistically significant correlations of training-related improvement (post – pre training) on behavioural measures of intelligence and performance on the flanker task as well as electrophysiological measures of area of the difference waveform and conflict (incongruent – congruent).

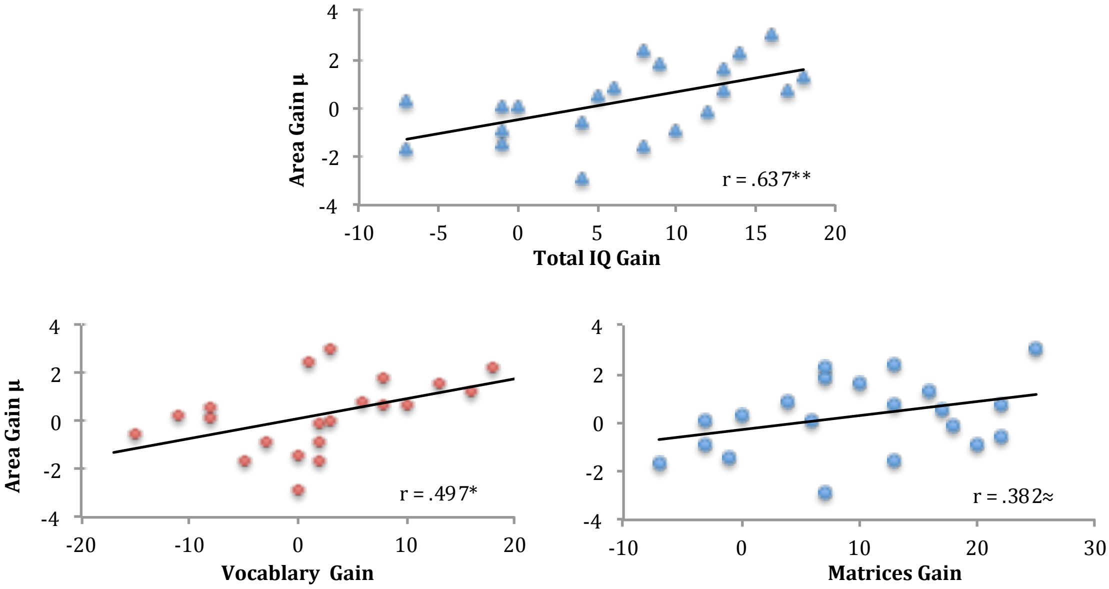


Figure 4.3.6. Correlations between area gain (post – pre training) with gains in verbal, fluid and total IQ scale scores.

4.3.5. Discussion

In this study we aimed to improve the efficiency of the attention-training program for pre-school children developed by Rueda et. al. (2005, 2012), trough the inclusion of several new exercises, increasing the number of session and integrating metacognitive scaffolding by means of a metacognitive feedback script. We investigated whether the inclusion of a feedback script, aimed to foster the emergence of metacognitive knowledge, could improve the effects of the attention-training program and the efficiency of executive attention underlying brain mechanisms. In order to do so, we compared the effects of attention training with and without the metacognitive-feedback script.

4.3.5.1 Effects of training on behavioural measures

We were able to replicate a study by Rueda et. al. (2012), as our results showed that training had no significant effect on behavioural performance using the flanker task. We found evidence of increased efficiency of the executive attention network for all groups, indicated by the reduction of conflict scores at the post-training session. Rueda et. al. (2012) suggested that the general reduction of conflict scores observed in their study could be explained by children reaching a sealing effect of performance due to task repetition at the post session. Our new data does not contradict this explanation. As shown in table 4.3.3 pre-training network scores were more variable (MF = 50, NF = 61, and AC = 64), while at post-training network scores were found more similar (MF = 28, NF = 25 and AC = 31). This suggests that repetition of the task might in itself be responsible for the improvement in conflict scores.

Interestingly, we found an overall increase in the percentage of errors committed during post-training sessions. That the children were getting less accurate might be related to task specific characteristics. The flanker task used in this study was programmed to adjust the time of target presentation in a trial-by-trial basis, according to participant´s performance in the previous trial. At the post-training session children showed a reduction in RT conflict scores and overall RTs, which resulted in faster stimuli presentation. The increased error rate might be due to difficulties in processing the stimuli. It is therefore difficult to interpret this result as a reduction of children´s efficiency in task performance.

4.3.5.2 Effects of training on brain activity

One of the main goals of our study was to assess the effect of attention training on the underlying neural mechanisms related to the executive attention network. Specifically we were interested to evaluate the differential effects of training strategy in ERPs related to conflict monitoring processes (N2/N450). Our strategy was to compare the modulation of ERPs by flanker incongruence before and after the training sessions. Previous developmental studies have demonstrated that flanker congruency modulates ERP components showing larger negative amplitudes for incongruent compared to congruent trials starting around 550 ms after stimuli onset with a more anterior distribution (Abundis-Gutiérrez et al., 2014; Rueda, Posner, et al., 2004). More over, several studies have revealed a decrease in amplitude of the N2/N450 component throughout childhood and adolescence (Abundis-Gutiérrez et al., 2014; Hämmerer et al., 2010; Lisa M Jonkman, 2006; Lamm et al., 2006). Similar to the study presented by Rueda, et. al. (2005), our results showed that for the age group of 4-5 year olds there were a small congruency effect at the pre-training session with a more anterior distribution. Specifically, results exhibited that the MF and the NF groups did not show any significant difference of mean amplitude between congruency conditions, but the AC showed a marginal difference at anterior and a significant difference at posterior electrode sites. Topographical maps displayed that even if the difference did not reach significance for the MF and NF group, the topographical distribution of the congruency effect was changed towards the expected more anterior direction.

We found evidence that attention-training affects the topographic distribution of the ERPs related to conflict monitoring, replicating previous studies (Rueda et al., 2012; Rueda, et al., 2005). Moreover, we discovered that this effect was enhanced by the implementation of metacognitive scaffolding. We observed that the MF group presented an increase in amplitude at middle and posterior electrode sites, as well as an increase in area at posterior sites. This result was found smaller for the NF group because of their marginal increase of amplitude difference at posterior sites. Accordingly, the patterns for the MF group was similar to the effect of training found for trained 6 year-olds by Rueda, et. al. (2005). Therefore our data supports the idea that the influence of cognitive training on brain activation resembles that of normal age related development by showing a more adult-like activation after training.

4.3.5.3 Relation between the effects of training on brain activity and intelligence measures

An increase of intelligence scores after training intervention, which was larger for the MF than for the NF group has been reported and is supported by the data of this study (Rueda et al., 2012; Rueda, Rothbart, et al., 2005). Interestingly, we discovered a correlation between the increase in mean amplitude difference and area at anterior sites and the increase in intelligence measures only for the MF group. Far-transfer effects from cognitive training into intelligence scores have been reported in previous studies (Bergman et al., 2011; M Buschkuehl & Jaeggi, 2010; Jaeggi et al., 2011a; Karbach & Kray, 2009; Rueda et al., 2012; Rueda, Rothbart, et al., 2005) and it has been suggested that far-transfer effects into intelligence measures are supported by the anatomical overlap of underlying shared brain structures (Duncan, 2000).

A recent study that assessed the differences in conflict monitoring between children with different intellectual capacities showed that gifted children elicited smaller N2 activation in frontal regions compared to children with average intelligence scores (Liu, Xiao, Shi, Zhao, & Liu, 2011). The authors suggested that the smaller N2 amplitude in gifted children is related to enhanced efficiency of neural functioning and more mature frontal functioning during conflict monitoring processing. Also, Liu et. al. (2011) suggested that gifted children´s enhanced conflict monitoring abilities are related to better pre-attention processing in detecting minor changes in conflict situations.

In contrast to Lui, et. al. (2011), our results indicated that an increase in intelligence scale scores was related to an increase in N2 amplitude and area. The discrepancy of results might in part be explained by the difference in children´s age between studies. While Liu et. al. (2011) conducted their study with 12-13 year old children, our study was conducted with pre-school aged children (4-5 year old). Abundis-Gutierrez et. al. (2014) showed that the N2 congruency effect was not present in 4-6 year-old children, however it increased and was more sustained for children 7-9 and 10-13 year old, until it decreased and became less sustained in adulthood. Likewise, behavioural studies showed a remarkable development of the executive attention network between 7 – 8 years reflected on a large decrease of conflict scores with a subsequent stability after 8 years up until adulthood (Davidson et al., 2006a; Pozuelos et al., 2014; Rueda, Fan, et al., 2004; Waszak et al., 2010). Integrating these findings our data suggests that N2 amplitudes may experience an increase of amplitude between 4 and 6 years, before they decrease subsequently as reported (Hämmerer et al., 2010; Lisa M Jonkman, 2006; Lamm et al., 2006). Therefore, the correlation of increased amplitude at N2 at anterior sites with the increase of intelligence scores after training may indicate an improved efficiency of shared underlying neural structures.

4.3.5.4 Differential effects between training strategies

We asked whether different training strategies produce different outcomes of the intervention. In fact, our results showed that MF and NF evidence different effects of attention-training. But what possible factors might influence these outcomes?

In his historical-cultural theory of development, Vygotsky suggested that a milestone in the development of higher mental processes happens when children acquire language as a tool for representing the world (Bodrova et al., 2011; Vygotsky, 1978a). For Vygotsky language has an instrumental value for cognition because it enables the abstract manipulation of information and assistance of cognitive processes. Also, through language it is possible to establish a social interaction that allows the transmission of necessary information and strategies that enables the emergence of metacognitive knowledge (Efklides, 2008; Salonen, Vauras, & Efklides, 2005). This process of transmission of knowledge and experience is exerted through what Vygotsky called the Zone of Proximal Development (Vygotsky, 1978a), which refers to the level of potential development determined by the actual developmental level and the development that is possible under the guidance of more capable peers.

In our study we developed and implemented a metacognitive feedback script based on Vygotsky´s idea of the zone of proximal development. The objective of the script was that through the interaction with the trainer children would be provided with a scaffold that would help them to direct their attention into important task features, which would then enable them to extract task-relevant information in order to build a task-metacognitive model and to develop strategies in order to improve their performance. A study conducted by Diamond & Lee (2011) indicated that educational interventions based on Vygotksy´s principles, and with a strong focus on language and social interaction, also improve cognitive control. Our data supported these findings, and suggests that the implementation of scaffolding intervention in children increases the effectiveness of cognitive training..

4.3.6 Conclusions

Our results from the present study provide further evidence of a beneficial effect of cognitive training interventions. Attention training appears to accelerate the developmental trajectory of conflict related processes by inducing brain activation with more adult-like pattern. Moreover, our study revealed that the inclusion of a metacognitive intervention boost near and far-transfer effects produced by the attention training. It is important to notice that our electrophysiological data presented in this study supports the evidence presented by Pozuelos et. al. (2014) where far-transfer effects of attention training into measures of intelligence were found enhanced by the implementation of the metacognitive intervention. In the present study we provided evidence that associated these effects with changes in the underlying brain structures that support cognitive control and processes related to intelligence (Duncan & Owen, 2000; Duncan, 2000; Rueda, Rothbart, et al., 2005). Further studies are needed in order to understand the nature of the influence produced on brain activation by metacognitive interventions and the importance of language in the emergence of cognitive control mechanisms and reasoning abilities.

4.4 Cognitive training influence on inhibitory control: enhancement of the effects of attention-training by means of metacognitive intervention.

4.4.1 Introduction

The ability to stop and inhibit automatic behaviours, thoughts and emotional responses is fundamental for experiencing a healthy and satisfactory life. Inhibitory control is a process that has been related to cognitive control mechanisms and is described as the capacity of supressing on-going motor or cognitive processes in order to adapt to changing and demanding situations (Aron & Poldrack, 2005; Hampshire et al., 2010; Munakata et al., 2011). As a cognitive control mechanism, it is proposed to be a core process of the executive attention network (Petersen & Posner, 2012; Posner & Petersen, 1990) and of the more general domain of executive functions (A. Diamond, 2013; Zelazo et al., 2004). Deficiencies in inhibitory control has been associated with a variety of clinical disorders (Aron & Poldrack, 2005; Iacono, Malone, & McGue, 2008), learning difficulties (Blair & Razza, 2007) and behavioural problems (Friedman et al., 2007).

Neuroimaging studies have revealed that a set of ventro-lateral prefrontal and subcortical structures are related to response inhibition processes (Aron, 2011a; Chikazoe et al., 2009b; Munakata et al., 2011). Within this network it has been suggested that the Inferior Frontal Junction (IFJ) and the pre supplementary motor area (pre-SMA) are needed to implement attentional detection and control, while the posterior inferior frontal gyrus (pIFG) is needed to implement inhibitory control (Chikazoe et al., 2009b; Hampshire et al., 2010; Munakata, Casey, & Diamond, 2004). Studies conducted with electroencephalography have identified two main event-related components (ERPs) that are related to inhibitory control processes as studied by the Go-NoGo task. First, the N2 ERP is characterized as a fronto-central negative deflection that peaks around 200 to 450 ms after stimulus onset and is related to conflict monitoring (Carter & van Veen, 2007; L M Jonkman, Sniedt, & Kemner, 2007; Nieuwenhuis et al., 2003; Veen & Carter, 2001). The second ERP is the P3 and is characterized by a positive deflection that peaks around 300 ms after stimulus onset and has been related to response inhibition (Bokura, Yamaguchi, & Kobayashi, 2001; Polich & Criado, 2006; Polich, 2007; Smith, Johnstone, & Barry, 2008).

Behavioural developmental studies of inhibitory control showed that this process exhibits a progressive development from early childhood into adulthood, indicated by a decrease of false alarm rates with age (Bedard et al., 2002; Williams, Ponesse, Schachar, Logan, & Tannock, 1999). This finding is supported by neuroimaging studies which demonstrated increased activation of prefrontal cortex regions for children compared to adults, during response inhibition in the Go-NoGo task (Luna & Sweeney, 2004; Tamm, Menon, & Reiss, 2002). In the same line , previous electrophysiological studies have shown a progressive developmental-related decrease of activation and latency of the N2 ERP, from children up to young adulthood (Johnstone et al., 2007; Johnstone, Pleffer, Barry, Clarke, & Smith, 2005; Lisa M Jonkman, 2006). In contraty to the developmental trajectory of the N2, the P3 ERP develops later and showed a linear increase across age. Jonkman (2006) presented that the NoGo-P3 effect is absent in 6 -7 year olds and starts to increase from late childhood up until adulthood.

In recent years a number of studies have been published on training-induced improvements and changes in plasticity of inhibitory control processes (for review see Spierer, Chavan, & Manuel, 2013). In a behavioural study Verbruggen and Logan (2008) evaluated practice induced automatic forms of inhibition. By manipulating the stimulus-response mapping in practice and test phases the authors revealed that response inhibition benefits by consistent stimulus-stop association, however when stimulus-response mapping is manipulated at the test phase (i.e. when the NoGo stimulus is reversed) then response at the test phase its slowed due to the habituation of the stimulus-stop mapping at the training phase (Verbruggen & Logan, 2008). These results indicated that with practice automatic processes progressively replaced top-down controlled inhibition of prepotent motor responses.

The automaticity of inhibitory responses was deduced from electrophysiological evidence presented by Manuel et. al. (2010) using a similar training paradigm than the one used by Verbruggen and Logan (2008). Their results demonstrated that after practicing a Go-NoGo task electrophysiological responses to NoGo stimuli showed a decrease in the activity of left parietal cortices, which correlated with the behavioural improvement in inhibitory control. This results suggests that inhibitory control training resulted in a progressive disengagement of frontal top-down control in favour of fast automatic responses (Manuel, Grivel, Bernasconi, Murray, & Spierer, 2010; Spierer et al., 2013).

In order to study the effects of top-down forms of inhibition Benikos et. al. (2013) conducted a training study using a Go-NoGo task with increasing difficulty levels by manipulating the reaction time deadline (Low = 1000 ms, medium = 500 ms, high = 300ms). Behavioural data exhibited an improvement in performance only for the medium difficulty group, while the low and high difficulty groups did not show any increase or decline in task performance. Moreover, the study found an increase in the P3 after training in the medium difficulty condition.

Another study conducted by Milner et. al (2009) implemented an inhibitory control training using the Simon says task (Holmes & Pizzagalli, 2011) and a version of an emotional Go-NoGo task (Chiu et al., 2008). Results of this study indicated that after inhibitory control training, participants showed improvements in behavioural performance on the flanker task, evidenced by faster reaction times (RT) on incongruent trials while maintaining similar accuracy. Here, the analysis of ERPs exhibited a reduction in N2 amplitude for incongruent trials after training. Moreover, participants showing the greatest pre-post decrease in the N2 amplitude displayed the largest reduction in RT conflict effect. Previous studies (Yeung & Cohen, 2006) have demonstrated that a smaller N2 amplitude is related to a decrease in processing of the irrelevant stimulus dimension of the trial (i.e. better attentional control). Millner et. al. (2012) suggested that a possible explanation for the reduction of the N2 ERP may be related to a practice enhancement of conflict resolution automaticity.

In order to study potential generalization of inhibitory control training in pre-school aged children, Thorell et. al. (2009) compared the effects of working memory and inhibitory control training in a series of cognitive control tasks. The results demonstrated that in contrast to working memory training that produced improvement also in non-trained tasks and evidenced far-transfer, inhibitory control training improved performance on inhibitory control trained tasks but failed to generalize improvements into non-trained tasks (Thorell et al., 2009).

Inhibitory control is a process that has been related to the executive attention network (Petersen & Posner, 2012; Posner & Petersen, 1990; Rueda, Posner, et al., 2005). Rueda et. al. (2005, 2012) tested the effects of an attention training program on several cognitive control measures in pre-school aged children. Results showed increased activation and shorter latencies of the N2 ERP component related to cognitive control after training. However this results was measured with a flanker task (Eriksen & Eriksen, 1974) and no measures of inhibitory control where obtained.

Training studies have also been conducted using a different strategy that is not directly related to computerized exercises, but instead uses a more "ecological" designed intervention. Diamond et. al. (2007) conducted a study where they assessed transfer effects of a curricula design intervention based on Vygotsky's ideas of executive function development and formed by 40 EF-promoting activities that included language (i. e. self-regulatory speech) and social interaction (i. e. dramatic play). Results indicated far-transfer effects to non-related EF tasks, such as the dots task and the flanker task. Specifically, results revealed that children that participated in the intervention improved more in the dot task and flanker task, especially under more demanding conditions (a. Diamond & Lee, 2007). This results evidenced support for Vygotsky's suggestions that language plays an important role in cognitive control development (Luria, 1965; Vygotsky, 1978a, 1997).

Metacognition is a theoretical framework that is used to explain how cognitive control mechanisms and language/knowledge interplay in order to control behaviour and cognition (Efklides, 2008; Flavell, 1979; Martinez &

Martinez, 2006; Shimamura, 2008). Metacognition refers to the ability to evaluate and control one´s cognitive processes and has been characterized into two main components: Metacognitive Control (MC) and Metacognitive Knowledge (MK) (Efklides, 2008; Schraw & Moshman, 1995; Shimamura, 2000). While MC has been related to aspects of cognitive control and their underlying brain structures (Fernandez-duque, Baird, & Posner, 2000a; Fernandez-duque et al., 2000b), MK has been related to the ability to extract relevant information from experiences, build it into a comprehensive strategy and systematic procedures to implement it in order to achieve goals (Schraw & Moshman, 1995). Metacognitive knowledge is continuously updated and enriched by information coming from conscious monitoring of cognition, for instance by observing the results of one's own and other people's actions as well as by interacting and communicating with others (Efklides, 2008). Thus, Efklides (2008) suggested that language plays an important role in the development and improvement of MK.

In the present study we are interested to evaluate the effects of combining both training strategies in inhibitory control processes. In a previous series of studies, Rueda et. al. (2005, 2012) showed that an attention-training intervention improves electrophysiological measures of conflict monitoring related to a flanker task. However, inhibitory motor response measures have not been included in these studies. It has been suggested that inhibitory control tasks, such as the Go-NoGo, activate conflict monitoring processes that are associated with the N2 ERP, suggesting that there is a common conflict monitoring mechanism engaged in cognitive control processes related to executive attention (Bokura et al., 2001; Falkenstein et al., 1999; Nieuwenhuis et al., 2003; Petersen & Posner, 2012). Thus we are interested to assess transfer effects of an attention-training program into inhibitory control processes related to the Go-NoGo task. More over, we are interested to evaluate if inhibitory control is impacted by the inclusion of a metacognitive feedback design to support the emergence of metacognitive knowledge. We expected to find improvement in both behavioural and electrophysiological measures of inhibitory control. Specifically, we expected that our attention-training program would produce decreased latencies and increased activation of both the N2 and the P3 ERP component. Moreover, due to the fact that the metacognitive intervention was designed in order to provide a scaffolding that would foster children's ability to extract task relevant information, we expected that children in the metacognitive intervention group to improve in behavioural measures that indexes behavioural regulatory abilities such as the d´ sensitivity index.

4.4.2 Method

4.4.2.1 Subjects

From the total sample of 107 children, 10 children were discarded because they dropped out and 24 did not complete the task either in the pre or the post training evaluation period. Thus a total of 73 pre-school children data (42 males; mean age: 64.2 months; SD: 6.9 months) was used for further analysis (table 4.4.1).

Group	*N*	*Gender*		*Mean Age (SD)*	*Mean IQ (SD)*
		Girls	*Boys*		
Control	28	11	17	64.4 (6.6)	104 (14.8)
Met-Fbck	25	11	14	63.9 (7.8)	105 (11.7)
Nor-Fbck	20	9	11	64.4 (6.6)	105 (12.5)

Table 4.4.1. Descriptive statistics for the sample.

4.4.2.2 Procedures

A high-density (128-channels) EEG system was used to register children's brain activation while they were completing a child friendly Flanker tasks. An experimenter was present throughout the session in the testing room. Children received plastic coins at the end of each block according to their balance of correct trials. At the end of the session children selected toys and school supplies in exchange for the plastic coins as a gift for their participation in the study. Experimental sessions took place at the Cognitive Neuroscience laboratory of the University of Granada.

4.4.2.3 Task and measures

4.4.2.3.1 Go/No-Go Task

The task we used to assess inhibitory control was a child-friendly version of the Go/No-Go task. At the beginning of each trial a fixation cross was displayed at the centre of the screen for a variable duration randomly selected between 800 to 1600 ms. The target stimuli consisted in a cartoon traffic light presented for 800 ms at the centre of the screen in the position of the fixation cross. If the traffic light shines green (Go) participants were asked to press with the right index finger the right button on the response pad, and to withhold the pressing if the traffic light shines red (No-Go). The task consisted on a total of 160 trials divided into two experimental blocks. In order to induce a prevalent pressing response the proportion of stimuli was manipulated so the presentation of the target was set for 75% Go trials (120) and 25% of No-Go trials (40). Participants where asked to respond as fast as possible and no feedback was presented after stimuli onset. A schematic representation of the experimental task is presented in figure 4.4.1.

Performance in the Go/No-Go task was assess by computing the d´ sensitivity index and slowing after error (SAE) index as measures of behavioural regulation.

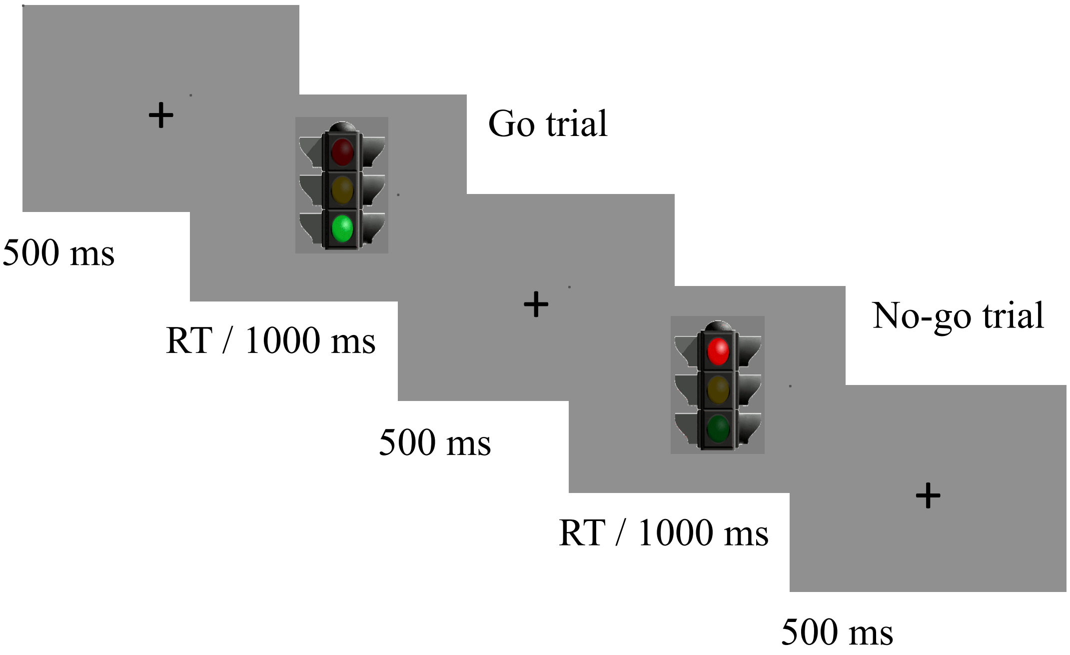


Figure 4.4.1. Schematic representation of the Go-NoGo task.

4.4.2.4 EEG recording and data processing

EEG was recorded using a 128-channel Geodesic Sensor Net 4.2 (EGI Software: www.egi.com). The EEG signal was acquired using a 100 to 0.01Hz band pass filter and digitized at 250Hz. Impedance for all channels was kept below 50KΩ. Pre-processing of continuous data was performed in EEGLAB version 13.2.2 (Delorme and Makeig, 2004). EEG data were filtered using a finite impulse response (FIR) band pass filter with 0.3 Hz high-pass and 30 Hz low-pass cutoffs (Passband gain: 99.0% (-0.1 dB), stopband gain: 1.0% (-40.0 dB), rolloff: 0.29 Hz). After filtering the data, the Fully Automated Statistical Thresholding for EEG artifact Rejection procedure (FASTER, Nolan et al., 2010) was employed for removing artifacts from the data. Using a predefined z-score threshold of ±3 for each parameter, artifacts were detected and corrected regarding single channels, epochs, independent components (based on the infomax algorithm, Bell and Sejnowski, 1995) and single-channel single-epochs. Remaining artifactual independent components and epochs containing artifacts were removed after visual inspection.

After artifact removal, event related potentials (ERP) were processed using the ERPLAb toolbox (Lopez-Calderon & Luck, 2014). Continuous data were segmented into target-locked epochs of 1400 ms long (-200 to 1200 ms) with a pre-stimulus baseline correction of 200ms. Artifact-free segments were averaged across conditions and participants within each training group, and re-referenced to the average of all channels. A per-subject criterion of a minimum of 15 artifact-free segments per experimental condition was established in order to be included in the grand-average for each age group. A total of sixty-eight children reached that criterion, 23 for the Control group, 24 for the Metacognitive-feedback Group and 21 from the normal-feedback group.

4.4.3 Results

The task used in the present study has not been tested before. Therefore, in order to assess the specific effects of the attention training program related to between group differences, we first examined the electrical activity in the pre-training session to characterize the modulation of ERP components by stimuli manipulation. In accordance with previous studies we expected to find modulation on ERP components related to inhibitory control in Go/NoGo paradigms, such as the NoGo-N2 and the NoGo-P3 (L. M. Jonkman, Lansbergen, & Stauder, 2003; Lisa M Jonkman, 2006; Manuel, Bernasconi, & Spierer, 2013; Manuel et al., 2010). After visual inspection of the average waveforms we detected several components (i.e. N1, P2, N2, P3a and P3p) that were further analyzed using peak amplitude, mean amplitude, area of difference waveform and fractional area latency as dependent measures.

Analysis of pre-training and training effects data were carried out with two different strategies. First, to examine the effects of task condition and training influence in ERP components we conducted a series of ANOVAs in order to detect differences related to stimuli manipulation and training intervention. Second, we conducted a series of Pearson´s correlations in order to understand the relation between ERP component modulation and behavioral data (i.e. d´, SAE and intelligence). For the training data changes in the Pre and Post sessions were further examined with planned comparisons given that changes were predicted after intervention, and correlations were computed to examine the relation between pre-post change in ERPs and behavioural measures. Only significant and marginal effects have been reported.

4.4.3.1 Target-Locked ERPs for pre training session

4.4.3.1.1 N1 component

The amplitude difference between Go and NoGo appears to be largest between 100 – 200 ms after stimuli onset (N1) (See fig. 4.4.2.). Peak Amplitude was extracted from anterior and medial electrode sites and was submitted into a 2 (position) x 2 (condition) repeated measures ANOVA. Results revealed a significant main effect of condition (F(1,67) = 10.25, p < .01) indicating a lower peak amplitude for the NoGo condition (M = -8.85 µv, SD = 3.45) compared to the Go condition (M = -7.97 µv, SD = 3.01)..

4.4.3.1.2 P2 component

Average waveform analysis also showed an amplitude difference that is maximal between 200 – 350 ms following target onset (P2) in frontal leads (See fig. 4.4.2.). Therefore, we extracted peak amplitude measures for the P2 (200-350 ms time window) from anterior and medial electrode sites and submitted this data to a 2 (electrode site) x 2 (condition) repeated measures ANOVA. Results revealed significant main effects of position (F(1,67) = 15.94, p < .001) and condition (F(1,67) = 9.71, p < .01). Peak amplitude was generally higher in anterior electrodes (M = 0.67 µv, SD = 2.04) than in posterior electrodes (M = -0.09 µv, SD = 1.74), and higher for the NoGo condition (M = -0.17 µv, SD = 0.17) than for the Go Condition (M = -0.76 µv, SD = 1.95) .

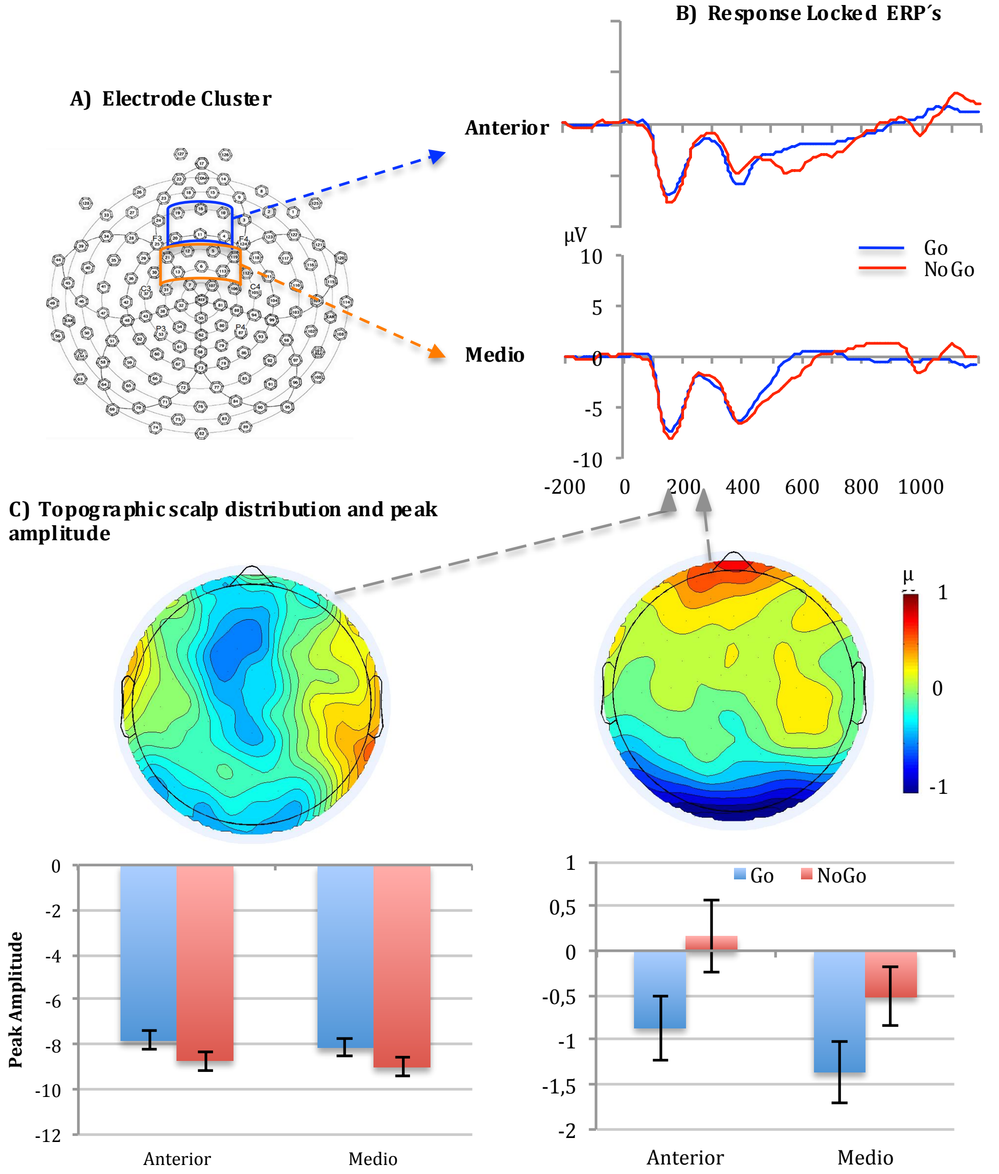


Figure 4.4.2. A) Electrode clusters sites, **B)** Response-Locked ERP´s representing Go and NoGo waveforms, **C)** Topography showing scalp distribution of difference waveforms corresponding to the N1 and the P2 ERP´s and **D)** Peak Amplitude of the N1 and P2 at each electrode site.

4.4.3.1.3 N2 component

Visual inspection revealed a negative deflection for the No-Go compared to the Go condition between 350 – 800 ms after stimuli onset. However, this deflection presented a different morphology in anterior electrodes sites compared to central electrodes. The anterior component waveform appeared to have a delayed onset (around 450 ms) and highest amplitude difference between Go and

NoGo conditions, while the central component appeared to have an earlier onset (around 350 ms) and less amplitude difference between conditions. Therefore we conducted separate analysis for each of the electrode sites.

Topographical distribution for the time window of the N2 shows wide-distributed negative effect throughout both hemispheres. Therefore we computed mean amplitude, area and fractional area latency for left, middle and right electrode sites for anterior and posterior N2 component respectively.

4.4.3.1.3.1 Anterior N2 (450 – 800 ms)

Mean amplitude was submitted into a 3 (Site: right, middle, left) x 2 (condition) repeated measures ANOVA, and indicated a significant main effect of condition (F(1,67) = 30.47, p < .001), showing lower mean amplitude for NoGo (M = -7.17 µv, SD = 2.38) than for the Go (M = -5.11 µv, SD = 2.42) conditions. We also observed a marginal site x condition interaction (F(1,67) = 2.74, p = .06), indicating that difference between Go and NoGo condition is higher in right (2.48 µv) than middle (2.04 µv) and left (1.66 µv) sites (See fig. 4.4.3).

Area and fractional area latency measures were submitted into a One-Way ANOVA with electrode site as factor. Results exibited no significant effect for area and latency (all f´s < 1).

Correlations

Pearson’s correlations revealed a significant positive correlation between mean amplitude difference (NoGo – Go) at medial electrode sites with matrices (r = .346, p < .01) and total IQ scores (r = .297, p < .05), as well as between mean amplitude difference (NoGo – Go) at right electrode site with matrices (r = .312, p < .01) and total IQ score (r = .279, p < .05).

Our results also demonstrated a significant negative correlation between area at medial electrode site with matrices (r = -.362, p < .01) and total IQ (r = -.284, p < .05), and between area at right electrode site and matrices (r = -.395, p < .01) and total IQ (r = -.345, p < .01). We also found that area at left electrode site was negatively correlated with matrices score (r = -.224, p = .06).

Latency measures were negatively correlated with d´ at left (r = -.447, p < .001), medial (r = -.389, p < .01) and right (r = -.419, p < .01) electrode sites; and with SAE in left (r = -.291, p < .05), medial (r = -.336, p < .01) and right (r = -.348, p < .01) sites. (see table 4.4.2).

4.4.3.1.3.2 Central N2 (350 – 800 ms)

Analysis of the central N2 was conducted with the same procedure as the one used for the anterior N2. Results revealed a significant main effect of condition (F(1,67) = 17.14, p < .001), indicating lower mean amplitude for NoGo (M = -1.81 µv, SD = 2.13) than for the Go (M = -0.93 µv, SD = 1.83) conditions. A significant site x condition interaction (F(1,67) = 5.72, p < .01), indicates that difference between Go and NoGo condition is higher in right (1.19 µv) than middle (0.49 µv) and left (0.97 µv) sites (See fig. 4.4.4).

Results of the separate One Way ANOVA´s for area and latency shows no significant effects (all f´s < 1) for any of the measures.

Correlations

A positive correlation was found between mean amplitude difference at left electrode site with SAE (r = .302, p < .05) and d´ scores (r = .236, p < .05), as well as between mean amplitude difference at medial electrode site with d' (r = .362, p < .05) and marginal significance with SAE scores (r = .232, p = .06) (see table 4.4.2).

Area at left electrode sites was negatively correlated with SAE (r = -.246, p < .05). Also, a marginal negative correlation was found between area at medial electrode site with SAE scores (r = -.216, p = .07) and with d´ (r = -.231, p = .06).

For latency measures we found a negative correlation with d´ at left (r = -.444, p < .001), medial (r = -.372, p < .01) and right (r = -.351, p < .01) electrode sites, and with SAE at medial electrode site (r = -.298, p < .05) (see table 4.4.2).

4.4.3.1.4 P3 component

Visual inspection revealed a positive deflection that was higher for the No-Go as compared to the Go condition between 550 – 1000 ms (P3) following target presentation with a centro-parietal distribution. Comparing central and parietal waveforms, we detected that the central P3 presented a slightly delayed latency onset (around 650 ms) compared to the parietal P3 (around 550 ms) (See fig. 4.4.5). Therefore we conducted separate analysis for each of the electrode sites using mean amplitude as dependent measures in a t-test to evaluate the difference between conditions. We as well used Pearson´s correlations to characterize the functional relation between mean amplitude, area and fractional area latency with behavioural measures (d´, SAE and IQ).

4.4.3.1.4.1 Central P3 (650 – 950 ms)

Mean amplitude measures were submitted into a two-tail independent sample t-test. Results show a significant difference between Go and NoGo amplitude (t(2,134) = -3.56, p < .001), indicating higher amplitude for the NoGo (M = 2.18 µv, SD = 2.02) compared to the Go condition (M = 0.72 µv, SD = 2.69).

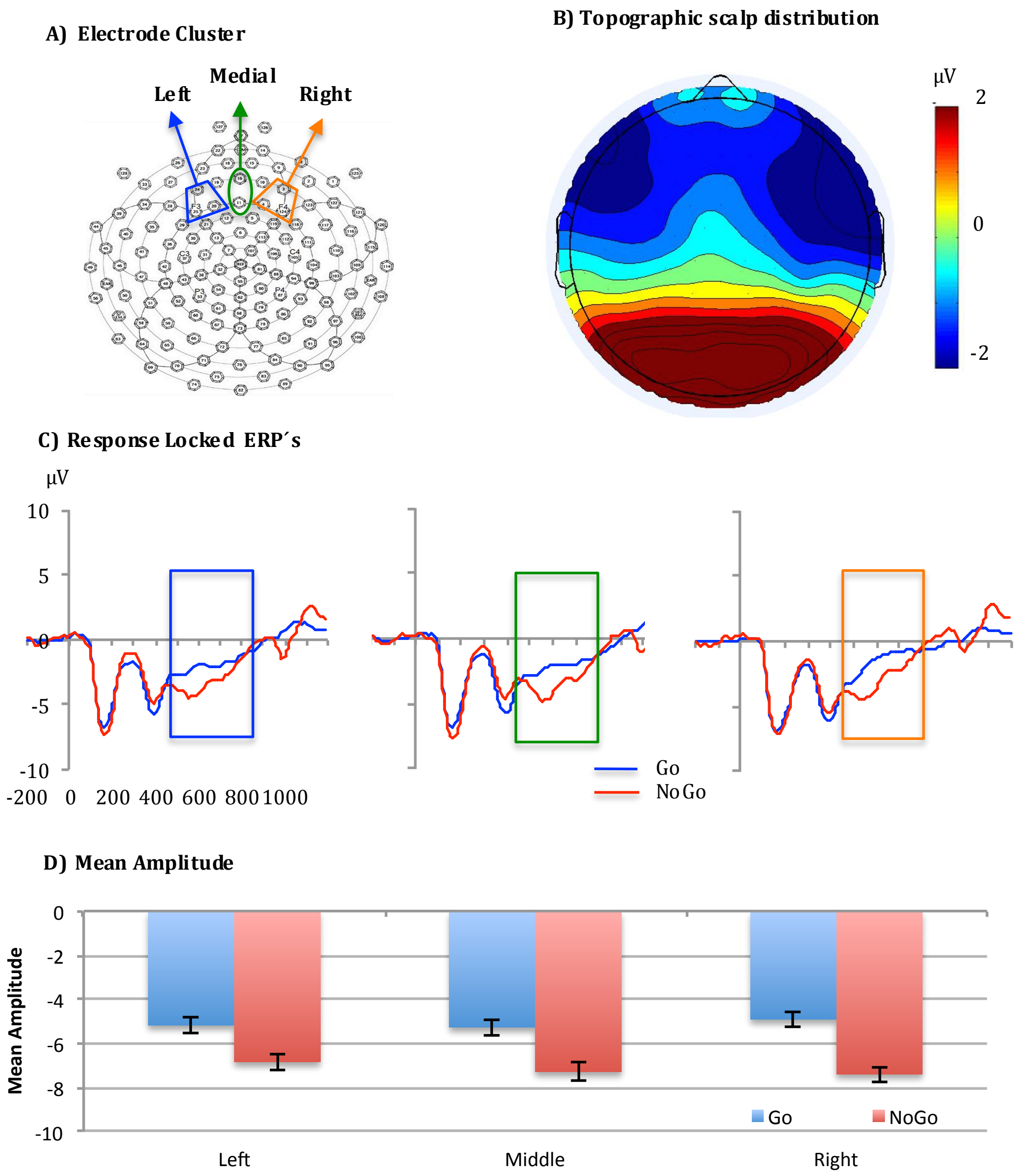


Figure 4.4.3. A) Electrode clusters sites, **B)** Topography showing scalp distribution of difference waveforms **C)** Response-Locked ERP´s representing Go and NoGo waveforms and **D)** Mean Amplitude Anterior N2 at each electrode site.

Correlations

A significant positive correlation was found between d´ and mean amplitude difference (r = .486, p < .001) and area (r = .507, p < .001). Latency was negatively correlated with d´ (r = -.256, p < .05) and SAE (r = -.479, p < .001) (see table 4.4.2).

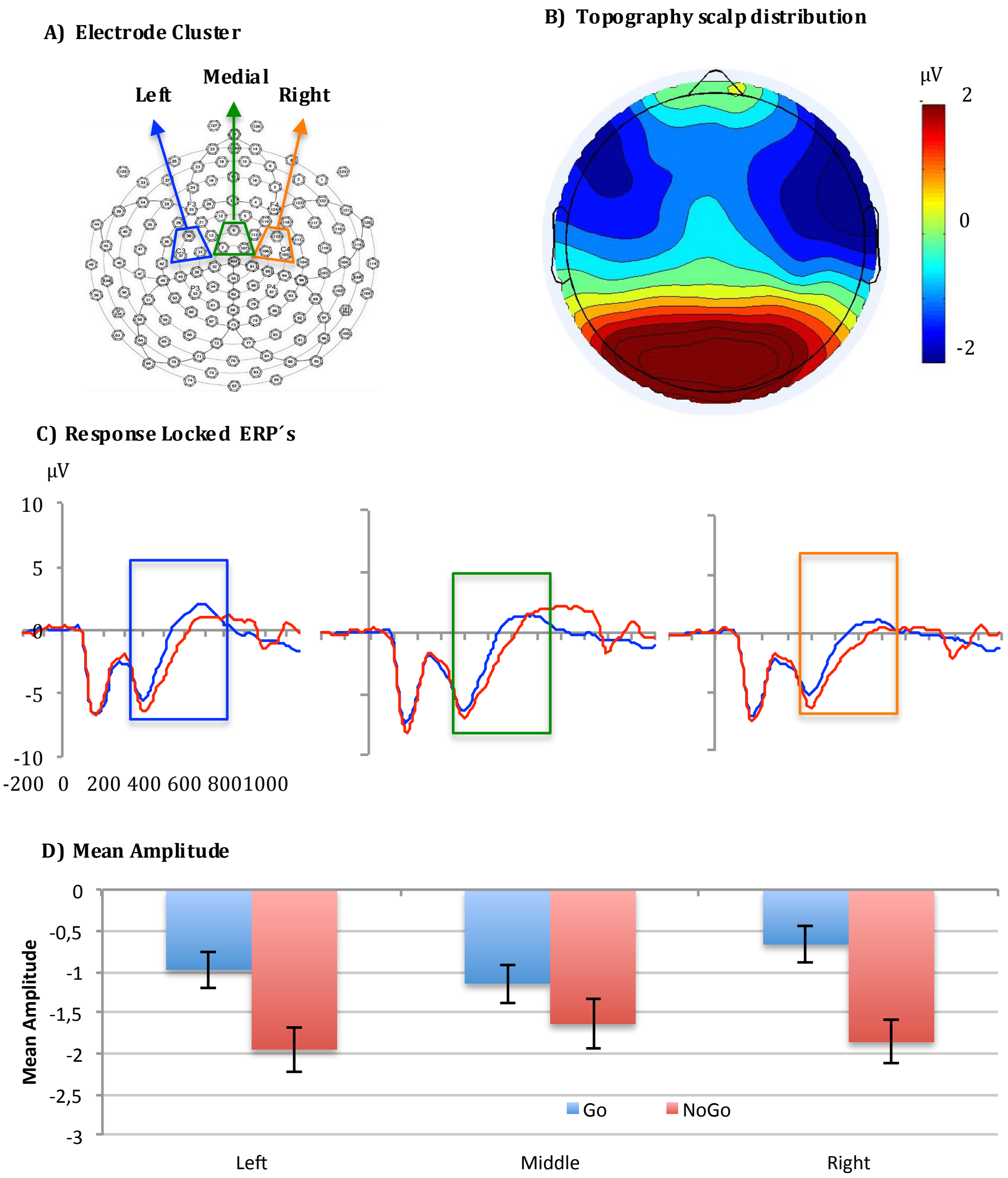


Figure 4.4.4. A) Electrode clusters sites, **B)** Topography showing scalp distribution of difference waveforms s **C)** Response-Locked ERP´s representing Go and NoGo waveforms and **D)** Mean Amplitude Central N2 at each electrode site.

4.4.3.1.4.2 Posterior P3 (550 – 1000 ms)

Mean amplitude measures were submitted into a two-tail independent sample t-test. Results show a significant difference between Go and NoGo amplitude (t(2,134) = -3.95, p < .001), indicating higher amplitude for the NoGo (M = 2.91 µv, SD = 2.44) compared to the Go condition (M = 1.44 µv, SD = 1.87).

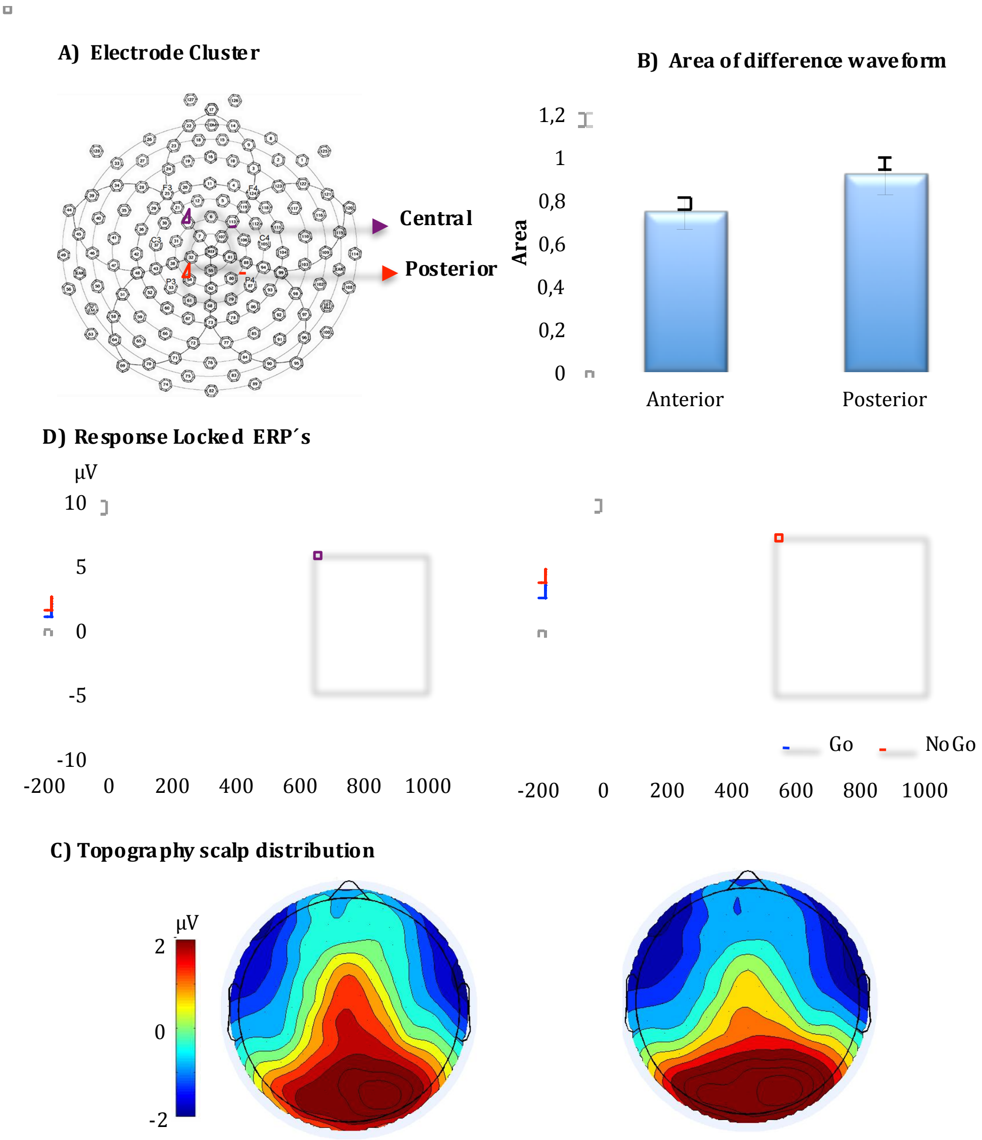


Figure 4.4.5. A) Electrode clusters sites, **B)** Area of difference waveform at each electrode site, and posterior P3 ERP´s, **C)** Response-Locked ERP´s representing Go and NoGo waveforms at each electrode site and **D)** Topography showing scalp distribution of difference waveforms at each electrode sites.

Correlations

A significant positive correlation was found between d´ and area (r = .245, p < .05), and marginal with mean amplitude difference (r = .209, p = .08) (see table 4.4.2).

				Behavioural Measures				
				Total IQ	***Fluid IQ***	***Verbal IQ***	***d´***	***SAE***
ERP´s Measures	*Anterior N2*	*Left*	*Inhibition Effect*	-	-	-	-	-
			Area	-	-.22≈	-	-	-
			Latency	-	-	-	-.47***	-.29*
		Medial	*Inhibition Effect*	.29*	.35**	-	-	-
			Area	-.28*	-.36**	-	-	-
			Latency	-	-	-	-.38**	-.33**
		Right	*Inhibition Effect*	.28*	.31**	-	-	-
			Area	-.35**	-.39**	-	-	-
			Latency	-	-	-	-.41**	-.34**
	Central N2	*Left*	*Inhibition Effect*	-	-	-	.24*	.30*
			Area	-	-	-	-	-.24*
			Latency	-	-	-	-.44***	-
		Medial	*Inhibition Effect*	-	-	-	.36*	.23≈
			Area	-	-	-	-.23≈	-.22≈
			Latency	-	-	-	-.35**	-.29*
		Right	*Inhibition Effect*	-	-	-	-	-
			Area	-	-	-	-	-
			Latency	-	-	-	-	-
	Central P3		*Inhibition Effect*	-	-	-	.49***	-
			Area	-	-	-	.51***	-
			Latency	-	-	-	-.25*	-.48***
	Posterior P3		*Inhibition Effect*	-	-	-	-	-
			Area	-	-	-	.25*	.21≈
			Latency	-	-	-	-	-

Table 4.4.2. Statistically significant and marginal correlations between behavioural and electrophysiological measures at the pre-training session.

4.4.3.2 Discussion

Results from the pre-training sessions revealed that the task condition influenced the amplitude of the N1, P2, N2 and P3 ERP components, which has recently been published as related to the Go-NoGo task both in children (Johnstone et al., 2007, 2005; Lisa M Jonkman, 2006; Spronk, Jonkman, & Kemner, 2008) and adults (Bokura et al., 2001; Falkenstein et al., 1999, 1995; Polich, 2007).

In early stages of stimuli processing our data revealed a modulation of the amplitude of the N1 fronto-central component by the NoGo condition. It has been suggested that the N1 component reflects the operation of visual discrimination mechanisms (Näätänen & Picton, 1987; Vogel & Luck, 2000). Similarly, our results demonstrated a modulation of the amplitude of the frontal P2 component by No-Go stimuli. Frontal P2 has been suggested to index appropriate classification of stimuli (Oades, 1998), however it has been suggested that its functional significance may have dissociable meanings according to scalp distribution (Benikos, Johnstone, & Roodenrys, 2013). The anterior P2, similar to the one found in our data, has been associated with processing and evaluation of relevant task stimuli (Potts, Liotti, Tucker, & Posner, 1996; Potts, 2004).

The analysis of the N2 and the P3 component where conducted by dividing each component in two different regions in order to be able to characterize their modulation through scalp distribution. The N2 component was divided into anterior and central sites, while the P3 component was divided into central and posterior sites due to the difference in morphology and latency that the waveform presented within regions. The anterior and central N2 were subsequently divided into left, central and right areas in order to analyse component lateralization.

As Expected, the anterior as well as the central N2 components showed larger negative amplitudes for the NoGo compared to the Go stimuli, with a slightly right lateralized scalp distribution. Even though this effect was somehow widely distributed across the scalp, it appears to be larger in frontal areas. Using different cognitive control tasks, several studies have shown that in young children the N2 component has larger amplitude, slower latencies and presents a more anterior distribution (Abundis-Gutiérrez, Checa, Castellanos, & Rosario Rueda, 2014; Checa, Castellanos, Abundis-Gutiérrez, & Rosario Rueda, 2014; Jonkman, 2006; Rueda et al., 2005; Rueda, Posner, Rothbart, & Davis-Stober, 2004).

The N2 component has been associated with conflict monitoring, a core process of the executive attention network implicated in the top-down regulation of our cognition and behaviour (Nieuwenhuis et al., 2003; Petersen & Posner, 2012; Posner et al., 2014, 2007b; Yeung et al., 2004). Our results provided further evidence that supports the relation between the N2 component and behavioural top-down regulation. Specifically, we found that the faster the latency of the N2 the higher discrimination (i.e. d´) and SAE scores. This result suggests that the faster the system is able to detect and resolve conflict, the better children´s behavioural regulation abilities.

Interestingly, our results showed relations between intelligence measures and the N2 at anterior sites. Specifically, fluid and general IQ were negatively correlated with area and positively correlated with mean amplitude difference. To our knowledge there is only one study that has documented a similar relation between cognitive control and intelligence. Using a flanker task Liu, Xiao, Shi, Zhao, & Liu, (2011) showed smaller activation of the frontal N2 component in gifted children compared to children with average intelligence. It has been suggested that cognitive control and processes that are targeted by intelligence tests share a network of underlying brain structures specifically related to frontal structures (Duncan & Owen, 2000; Duncan, 2000), and that reasoning abilities are built upon more basic processes such as perceptual control (Demetriou et al., 2008; Kane & Engle, 2002; Unsworth & Engle, 2005). In this line, our results provided evidence that further supports the relation of cognitive control process related to the executive attention network and intelligence measures. To our knowledge, this is the first study that found evidence of a relation between electrophysiological measures of inhibitory control and intelligence in pre-school age children.

Consistent with previous inhibitory control studies, we also found that the NoGo condition produced higher amplitudes of the P3 component at both central and parietal sites (Falkenstein et al., 1995; Johnstone et al., 2007; Spronk et al., 2008). In recent models of inhibitory control, the P3 component has been associated with attentional-inhibitory processes that facilitate decision making (Polich, 2007; Smith et al., 2008). In contrast to previous developmental studies that showed an absence of NoGo-P3 in young children (Johnstone et al., 2005; Lisa M Jonkman, 2006) our results exhibited an activation of the P3 component at a relatively young age. Moreover, our data suggested that this component is related to behavioural measures indicating that better discrimination (i.e. higher d´ scores) and behavioural regulation (i.e. higher SAE scores) were related to largest area, mean amplitude differences and faster latency of the P3 at central sites (and moderately with posterior sites).

After having characterized the modulation of the ERP components in the Go-NoGo task, we conducted a series of analysis in order to evaluate the influence of the attention-training program in behavioural and ERP measures. We were interested specifically to assess the transfer effects of attention training into inhibitory control and its underlying brain dynamics. In the following section we will focus our analysis in the N2 and P3 components and how training-related changes in behavioural and electrophysiological measures are related.

4.4.3.2 Cognitive training influence on behavioural measures

To assess the effect of training on various behavioural measures we conducted a set of repeated measures ANOVA with session (Pre, Post) and group (Metacognitive-Feedback (MF), Normal-Feedback (NF) and Active Control (AC)) as factors using the d´ and the SAE indexes as dependent measures. Then we examined changes in the Pre vrs Post session scores within each group using planned contrasts given that changes where predicted after intervention. Pre and Post training d´ and SAE data per training group are presented in table 4.4.3. To be included in the analyses, participants must not have had a percentage of errors exceeding 2 SD of the mean of its particular age group. However, no one of the children participating met the exclusion criterion..

Group	*DV*	*Pre*	*Post*	*Planned Contrasts*
Met-Fbck	SAE	35.9 (46.8)	28.2 (48.4)	n.s.
	d´	1.23 (0.7)	1.58 (0.69)	8.11**
Nor-Fbck	SAE	38.4 (38.6)	8.7 (45.7)	5.14*
	d´	1.28 (0.4)	1.53 (0.7)	3.44≈
Control	SAE	41.8 (47.9)	21.8 (39.5)	2.66≈
	d´	1.31 (0.7)	1.48 (0.6)	n.s.

Table 4.4.3. Pre and post-training mean (SD) of RT´s and percentage of errors are presented for each group.

4.4.3.2.1 d´

The d´ sensitivity index was calculated following the formula: d´= z (FA) – z (HR), where the z score of the hit rate (HT, signal items) is subtracted from the z score of the false alarms rate (FA, noise items). D-prime values of 0 or below indicate that subjects where either unable to discriminate any signal from noise or were not performing the task as instructed.

Results of the ANOVA contrasting the Pre and Post training scores revealed a significant main effect of Session for d´ scores (F(1,70) = 7.04; p < .01), indicating an increase of the d´ in the Post (M = 1.53, SD = 0.65) compared to the Pre (M = 1.27, SD = 0.63) training scores. Despite the non-significant group x session interaction, planned contrasts showed a significant increase in d´ index score for the MF group (F(1,70) = 8.11 , p < .01), marginal increase for the NF (F(1,70) = 3.44, p = .06) and not significant increase for the AC group (F(1,70) = 1.16, p = .16) (See table 4.4.3).

4.4.3.2.2 Slowing After Error (SAE)

The SAE was computed by subtracting the mean RT for correct Go trials preceded by a correct response from the mean RT for correct Go trials preceded by an error. Results of the ANOVA revealed a significant main effect of session (F(1,70) = 7.04, p < .01), indicating a decrease in SAE in the Post (M = 20.15, SD = 44.82) compared to the Pre (M = 38.66, SD = 44.35) training scores. Subsequent planned contrast revealed that the decrease in SAE was significant for the NF group (F(1,70) = 5.14 , p < .05) and marginally significant for the AC group (F(1,70) = 2.66, p = .09) and not significant for the MF group (F < 1) (See table 4.4.3).

4.4.3.2.3 Training influence on Target-Locked ERPs

After analyse the effects of stimuli manipulation in the ERP´s waveform and characterizing modulation of each component, we conducted a series of analysis in order to evaluate the influence of attention training in brain activation. We are interested on studying how attention-training impact brain activity related to cognitive control processes, therefore further analysis were conducted on ERP´s that has been associated with cognitive control, and shows significant correlations with behavioural measures at the pre-training session (i.e. N2 and P3). Data was analysed following the same strategy used for pre-training data using mean amplitude, area of difference waveform and fractional area latency as dependant measures.

4.4.3.2.3.1 Anterior N2 (450 – 800 ms)

Mean amplitude measures were submitted into a 2 (session) x 3 (laterality) x 2 (condition) repeated measures ANOVA using training group as between subject factor. Results revealed a significant main effect of session (F(1,65) = 216.80, p < .001) and condition (F(1,65) = 43.97, p < .001), indicating that mean amplitude was higher for the post-training (M = -1.89 µv, SD = 3.38) compared to the pre-training session (M = -6.11 µv, SD = 3.13), and for the Go condition (M = -3.11 µv, SD = 2.63) compared to NoGo condition (M = -4.89 µv, SD = 1.92).

A 2 (session) x 3 (laterality) repeated measure ANOVA with training group as a between subject factor was used to asses area and latency data. Our results showed no significant main effect nor significant interactions with area measures, while for latency results exhibited a significant main effect of session (F(1,65) = 4.86, p < .05) indicating slower latencies in the pre-training (M = 596 ms, SD = 69) compared to the post-training session (M = 572 ms, SD = 62). We also found a significant session x laterality interaction, indicating an increased reduction of latency between pre and post training session in left electrode sites (47 ms) compared to middle (17 ms) and right (8 ms). Planned contrasts revealed that this decrease was significant for the MF (F(1,65) = 10.90, p < .01) and for the NF (F(1,65) = 7.73, p < .01).

4.4.3.2.3.2 Central N2 (350 – 800 ms)

Results for mean amplitude data demonstrated a significant main effect of session (F(1,65) = 16.92, p < .001) and condition (F(1,65) = 39.45, p < .001), indicating higher mean amplitude for post-training (M = -0.64 µv, SD = 1.31) compared to pre-training (M = -1.36 µv, SD = 1.91) and for Go (M = -0.52 µv, SD = 1.06) compared to the NoGo condition (M = -1.42 µv, SD = 2.01). A significant interaction effect laterality x condition was also found (F(1,65) = 11.77, p < .001), indicating higher difference between Go and NoGo conditions for the right electrode sites (1.32 µv) compared to left (1.01 µv) and middle (0.53 µv) electrode sites.

Analysis of area data showed no significant effects, however planned contrasts exhibited an increase in area in the right electrode sites (F(1,65) = 5.84, p < .05) for AC. Analysis of latency revealed a significant main effect of session (F(1,65) = 11.16, p .01) indicating longer latencies for the pre-training (M = 555 ms, SD = 61) as compared to the post-training session (M = 523 ms, SD = 55). We also found a significant session x laterality x group interaction (F(4,122) = 2.90, p < .05). Planned contrasts revealed a significant decrease in latencies in left (F(1,61) = 8.47, p < .01) and right (F(1,61) = 19.41, p < .001) for the MF group (See fig. 4.4.6) and a marginally significant decrease in left (F(1,61) = 3.27, p = .07) and middle (F(1,61) = 3.04, p = .08) electrode site for the NF group (See fig. 4.4.7)..

Correlations

For MF group, a significant negative correlations was found between central N2 Latency and d´ at left electrode sites (r = -.478, p < .05) and with SAE at middle electrode sites (r = -.526, p < .05) (see table 4.4.4).

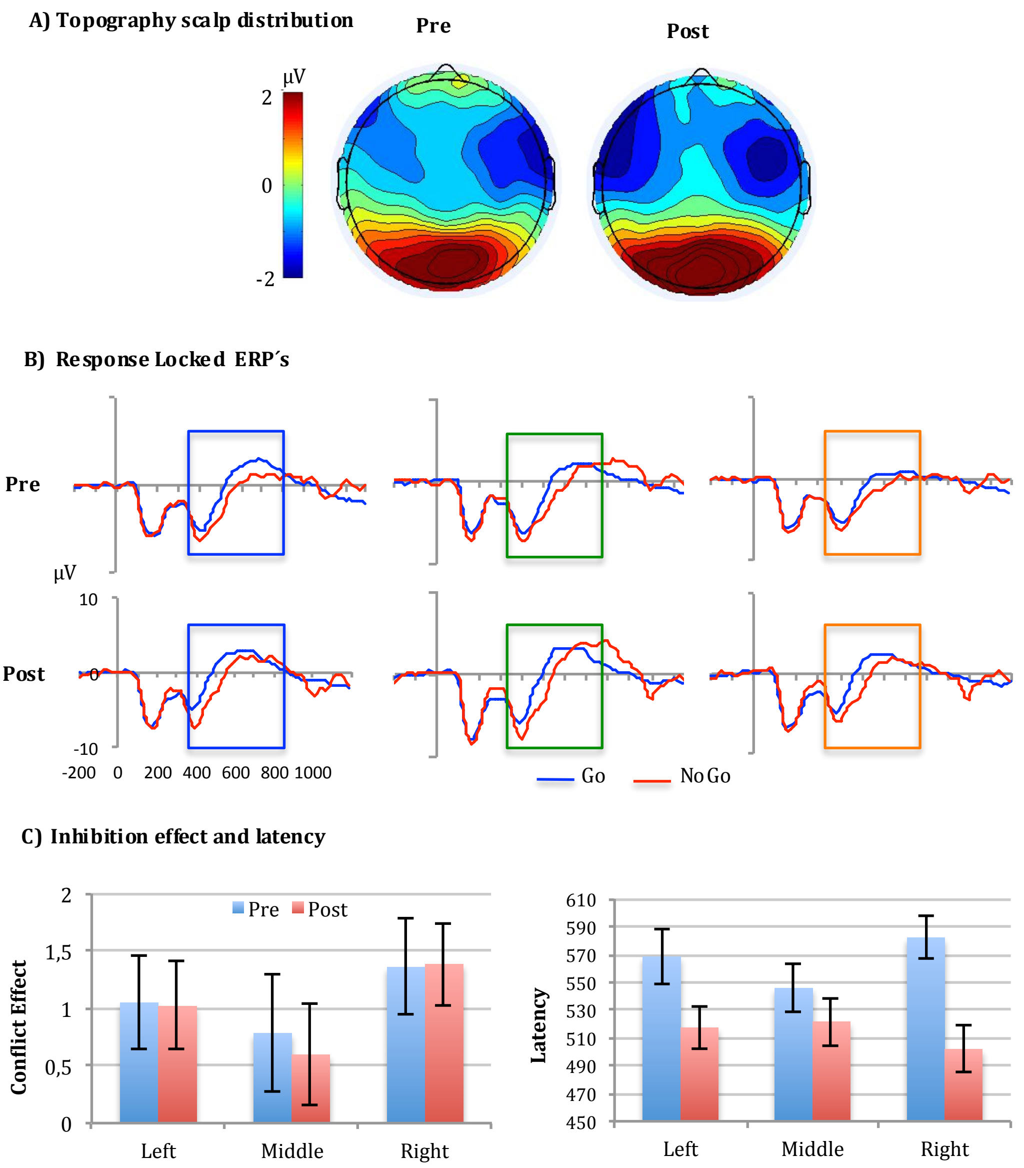


Figure 4.4.6. Metacognitive Feedback group pre and post training representing **A)** Topography showing scalp distribution of difference waveforms, **B)** Response-Locked ERP´s representing Go and NoGo waveforms at each electrode site and **C)** Inhibition effect (NoGo – Go) and latency values at each electrode site for the Central N2.

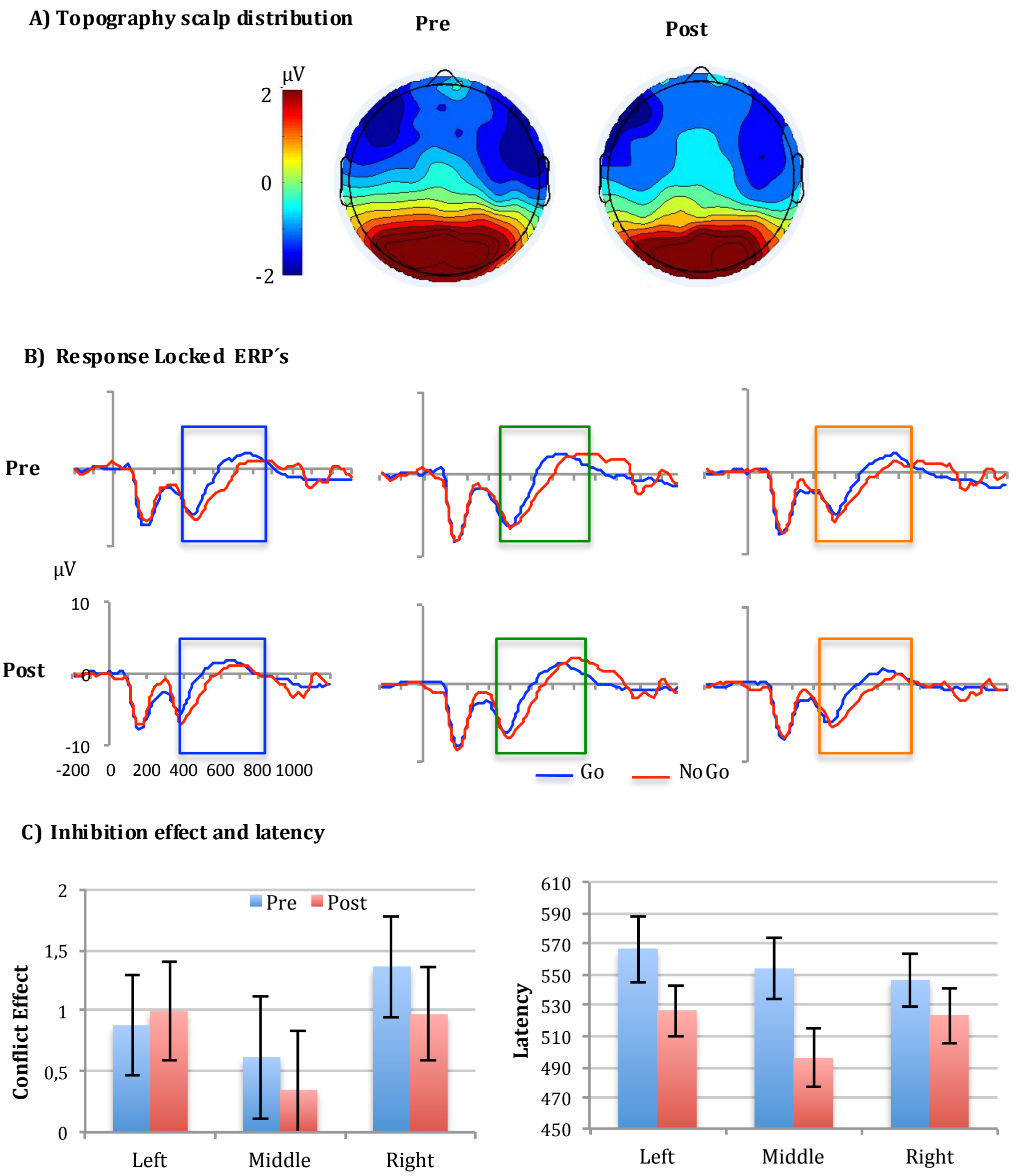


Figure 4.4.7. Normal Feedback group pre and post training representing **A)** Topography showing scalp distribution of difference waveforms, **B)** Response-Locked ERP´s representing Go and NoGo waveforms at each electrode site and **C)** Inhibition effect (NoGo – Go) and latency values at each electrode site for the Central N2.

4.4.3.2.3.3 Central P3 (650 – 950 ms)

Mean amplitude data was analyse by means of a 2 (session) x 2 (Condition) repeated measures ANOVA with group as between subject factor. Results revealed a significant main effect of condition (F(1,65) = 91.94, p < .001) indicating higher mean amplitude for the NoGo (M = 2.26 µv, SD = 1.44) compared to the Go condition (M = 0.87 µv, SD = 1.18).

A 2 (Session) repeated measure ANOVA with training group as a between subject factor was used to asses Area and Latency data. While no significant results were obtained for Area, for Latency measures results revealed a significant main effect of session (F(1,65) = 8.63, p < .01) indicating a slower latencies in the pre-training (M = 804 ms, SD = 35) compared to post-training session (M = 771 ms, SD = 39). Subsequent planned contrast show that the decrease in latency was significant for MF group (F(1,65) = 6.29, p < .05) (see fig. 4.4.8) and marginal for NF group (F(1,65) = 2.70, p = .10) (see fig. 4.4.9).

4.4.3.2.3.4 Posterior P3 (550 – 1000 ms)

Results for mean amplitude measures show a significant main effect of condition (F(1,65) = 43.46, p < .001) indicating higher mean amplitude for the NoGo condition (M = 2.64 µv, SD = 1.31) compared to Go condition (M = 1.34 µv, SD = 1.08). Area analysis revealed a marginal Session x Group interaction (F(1,65) = 2.51, p = .08) showing an increased in area for the MF group (0.27), and a decrease in area for the NF (-0.76) and AC (-0.32) groups.

Results for latency measure shows a significant main effect of session (F(1,65) = 7.08, p < .01) indicating faster latencies in the post-training (M = 742 ms, SD =41) compared to the pre-training (M = 776 ms, SD = 41). Also, a marginal main effect of group (F(1,65) = 2,52, p = .08) was found indicating that faster latencies for the NF group (M = 733 ms, SD = 57) than the AC (M = 768 ms, SD = 54) and the MF groups (M = 774, SD =53). Subsequent planned contrast show that the reduction in latency was significant only for the MF group (F(1,65) = 4.44, p < .05) (see fig. 4.4.8).

Correlations

For the MF group, results shows a significant negative correlation between Central P3 decrease in latency and increase in SAE scores (r = -.466, P < .05) and between decrease in Posterior P3 latency and increase d´ scores (r = -.524, p < .05). Also, we found that increase in area for the Posterior P3 was positively correlated with the increase in d´ index (r = .423, p < .05). There where no significant correlations for the NF group (see table 4.4.4).

				Meta-Fdbck		***Normal-Fdbck***	
				d´	***SAE***	***d´***	***SAE***
ERP´s Measures	***Central N2***	***Left***	*Inhibition Effect*	-	-	-	-
			Area	-	-	-	-
			Latency	-.48*	-	`-	-
		Medial	*Inhibition Effect*	-	-	-	-
			Area	-	-	-	-
			Latency	-	-.53*	-	-
		Right	*Inhibition Effect*	-	-	-	-
			Area	-	-	-	-
			Latency	-	-	-	-
	Central P3		*Inhibition Effect*	-	-	-	-
			Area	-	-	-	-
			Latency	´	-.46*	`-	-
	Posterior P3		*Inhibition Effect*	-	-	-	-
			Area	.42*	-	-	-
			Latency	-.52*	-	-	-

Table 4.4.4. Statistically significant and marginal correlations between behavioural and electrophysiological measures at the after raining for each training goup.

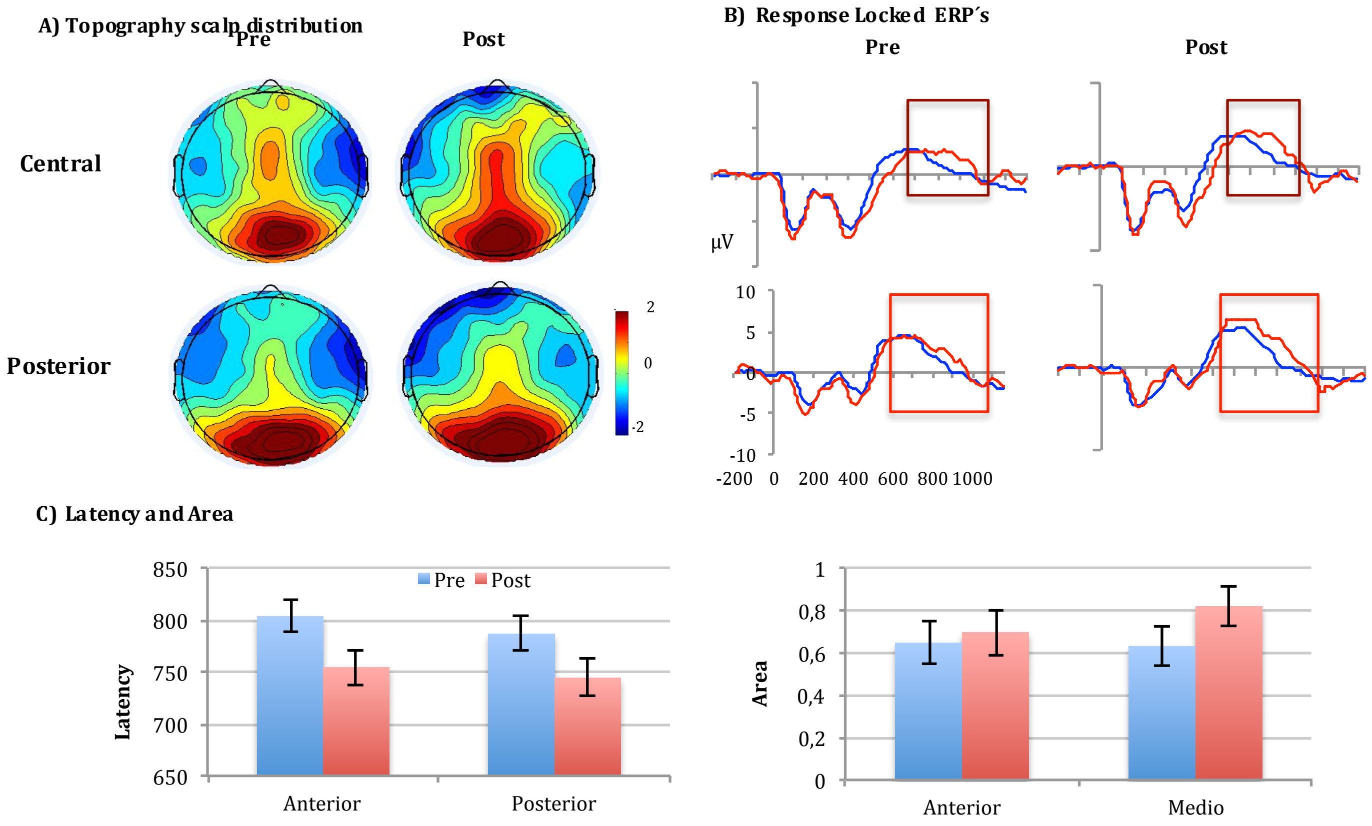


Figure 4.4.8. Metacognitive Feedback group pre and post training representing **A)** Topography showing scalp distribution of difference waveforms, **B)** Response-Locked ERP´s representing Go and NoGo waveforms at each electrode site and **C)** Latency and Area of the P3 central and P3 posterior.

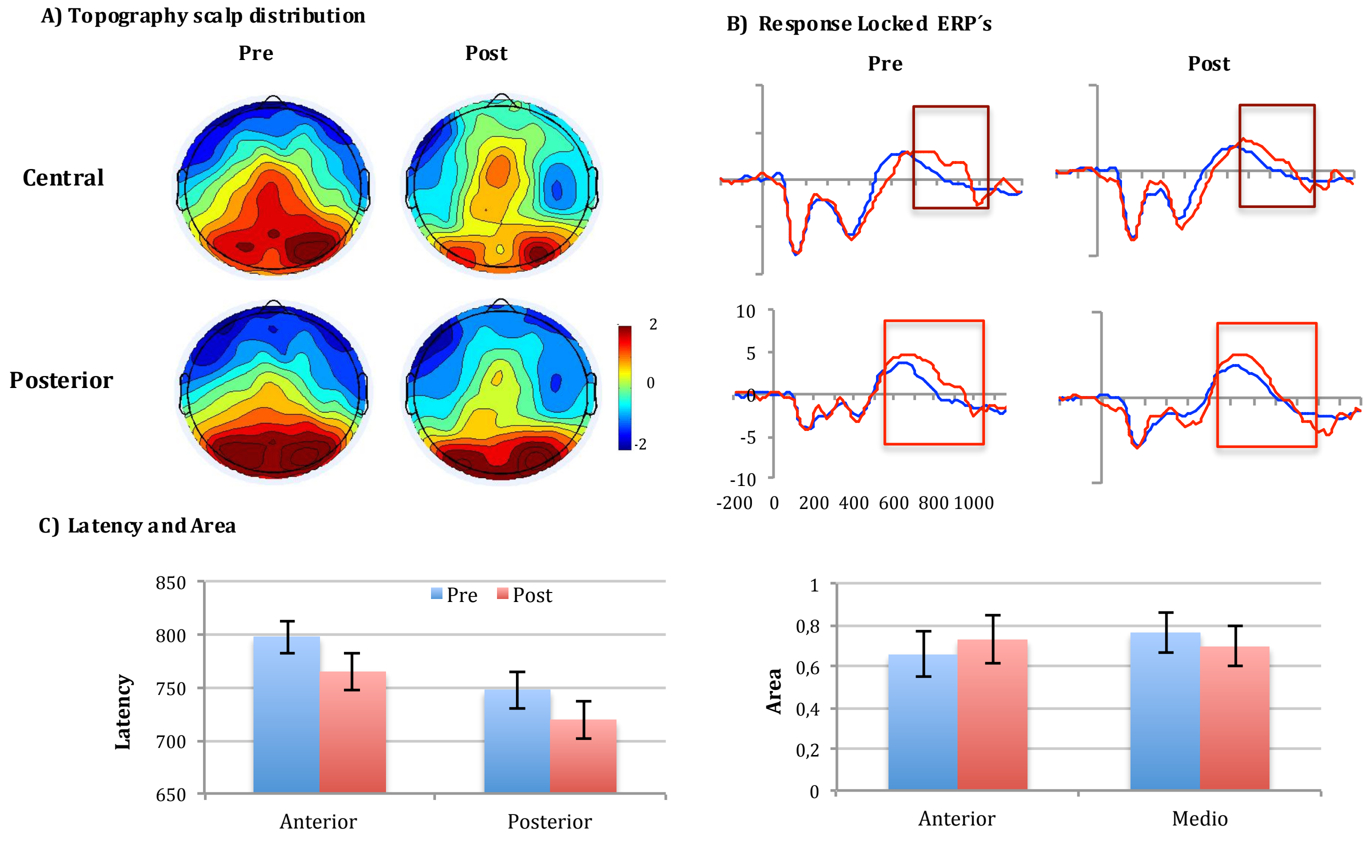


Figure 4.4.9. Normal Feedback group pre and post training representing **A)** Topography showing scalp distribution of difference waveforms, **B)** Response-Locked ERP´s representing Go and NoGo waveforms at each electrode site and **C)** Latency and Area of the P3 central and P3 posterior.

4.4.4 General Discussion

In the present study we aimed to evaluate transfer effects of an attention-training program on behavioural and electrophysiological correlates of inhibitory control processes in pre-school age children. Inhibitory control is a core function of the executive attention network related to control and regulation of cognition, behaviour and emotion (Kanske & Kotz, 2011; Kanske, 2012; Petersen & Posner, 2012; Posner & Petersen, 1990; Posner et al., 2007b).

Behavioural studies have shown that the executive attention network shows a protracted development throughout childhood, with a period of mayor development between 4 and 7 years of age (Pozuelos et al., 2014; Rueda, Fan, et al., 2004; Waszak et al., 2010). This nation is supported by neuroimaging studies that showed more immature patterns of brain activation during childhood, evidenced by a more widely and diffuse activation of the pre-frontal cortex during cognitive control tasks (Bunge & Wright, 2007; Casey, Galvan, & Hare, 2005; Casey et al., 1997) as well as higher amplitudes and latencies in ERPs related to control processes during childhood (Abundis-Gutiérrez et al., 2014; Purificación Checa et al., 2014; Lisa M Jonkman, 2006; Rueda, Posner, et al., 2004; Spronk et al., 2008).

Based on this evidence, we wanted to assess the benefits of an attention-training program on inhibitory control process during pre-school ages. Moreover, we wanted to evaluate if the inclusion of a metacognitive component would improve the outcomes of the attention-training program.

4.4.4.1 Inhibitory control training influence on behavioural measures

In previous training studies conducted by our group, we could show that while it is difficult to detect training-related improvements in behavioural measures on tasks that elicit conflict (i.e. Flanker Task), our data suggested that training produces an impact on the activation of the underlying brain structures (Rueda et al., 2012; Rueda, Rothbart, et al., 2005). Our actual study provides further evidence of the beneficial effects of attention-training in both behavioural and brain activation measures related to inhibitory control processes.

Our behavioural data showed that after training, children in both training groups improved their ability to discriminate between conditions although the effect was only moderate for the NF group. This results suggests that the attention-training improved children´s perceptual discriminatory ability, and that this improvement is even greater when the metacognitive training is included. Furthermore children in the NF and the AC group exhibited a decrease in behavioural regulation scores after training (index by the SAE), while children in the MF group gained similar scores at the pre and post session. The slowing after error (or post error-slowing) is an index of behavioural regulation and related to the ability of the individual to regulate their response time after becoming aware of having made a mistake (Gupta, Kar, & Srinivasan, 2009; Jentzsch & Dudschig, 2009; Rabbitt & Rodgers, 1977). Our results demonstrated that while children in the NF and AC groups showed a decrease in the compensatory strategy of slowing the response after committing an error, children in the MF group showed similar levels of compensation in pre- and post-training sessions.

To our knowledge there is only one training study that specifically tested transfer effects of inhibition training at pre-school age. Thorell et al. (2009) evaluated near and far-transfer of a working memory (i.e. visuo-spatial WM) and an inhibitory control training (i.e. Go-NoGo, Stop-signal, Flanker) in a group of 4 – 5 year old children. After a 5 week intervention program, their results showed that children trained in inhibitory control did show improvements in performance on trained tasks but failed to generalize the effects into un-trained tasks, whereas children in the working memory training did show a generalization of the effects into untrained verbal and spatial WM tasks, as well as into attention measures. In contrast to study of Thorell et. al. (2009), we found that attention-training (based on similar exercises based on similar paradigms) did show generalization of training into other measures of attention. A possible explanation for these different effects may be that although in both studies training exercises were focussed on training similar processes (motor response inhibition, stopping of on-going response and conflict resolution) the amount of training time could have made the difference as in Thorell´s study training session time was 15 min, while in our study the session time was 45 min. Thorell et. al. (2009) suggested that in their study the time devoted to the key neural process being trained was to short to promote improvement and brain plasticity of the underlying brain structures (Thorell et al., 2009). Another potential explanation is that our training program was composed of exercises that trigger many more cognitive control mechanisms additional to inhibitory control (i.e. cognitive flexibility, conflict monitoring, selective attention, etc.) which may have produced a broader effect on the executive attention network and promoted more efficient transfer effects into processes related to this network.

4.4.4.2 Inhibitory control training influence in ERP´s

There have been many studies that have assessed the effects of training on inhibitory control in adults, revealing several positive outcomes in terms of behavioural performance and brain activation measures (for review see, Spierer et al., 2013). Yet, to our knowledge, this is the first study that reports the effects of a training program on ERPs in pre-school aged children. In line with previous studies (Rueda et al., 2012; Rueda, Rothbart, et al., 2005) our results showed that the effect of training on brain activation influences the level of engagement and the speed of activation of the underlying brain structures.

Our pre-training analysis of subjects revealed that faster latencies in the N2 component were related to a higher d´ discrimination index. The N2 is an ERP that has been related to conflict monitoring processes at response selection (Botvinick et al., 2001; Nieuwenhuis et al., 2003). Furthermore we could demonstrate a decrease in latency of the N2 after training, which was related with the increase in d´ only for the MF group. These results suggest that after training children showed increased discrimination between Go and NoGo stimuli, and that the underlying brain structures that support discrimination were engaged faster in order to facilitate this process. Previous developmental studies related to inhibitory control and the Go-NoGo task have shown a linear decrease in latency of the N2 related to age (Johnstone et al., 2005; L. M. Jonkman et al., 2003; Lisa M Jonkman, 2006). Taken together, these findings suggest that training influences the efficiency of the neural processes that underlie response selection, and that the influence of training is similar to that of the normal course of development.

Our data revealed that the P3 component showed a decrease in latency and a moderate increase in amplitude associated with the increase in the d´ index, only for the MF group. Developmental studies have shown that the P3 component develops until late childhood, and similar to the N2, shows a decrease in latency with age (Johnstone et al., 2005; Lisa M Jonkman, 2006). Consistent with the hypothesis of the P3 being related to attentional-inhibitory processes that facilitate decision making (Polich, 2007; Smith et al., 2008), our results showed that the increase in amplitude and decrease in latency of the P3 is associated with improved d´ scores after training. These results present further evidence that training-related behavioural changes are supported by plasticity of the underlying brain mechanisms that support those processes.

4.4.3. Differences between training strategies: possible explanations

Is interesting to note how the impact of attention-training is enhanced when it is supported by a metacognitive intervention as was shown in our study. We provide evidence in favour of the hypothesis that regulation of thoughts and emotions is improved by the interplay between control mechanisms and metacognitive knowledge (Fernandez-duque et al., 2000b; Flavell, 1979, 2000; Shimamura, 2000). Previous studies have shown improvement in cognitive control processes by interventions designed based on social interaction and the use of language as a self-regulation tool (Diamond & Lee, 2007; Diamond, 2012). The interactive relation established with the trainer provided children with guidance and support on how to direct their attention in order to extract task-relevant information, to build it into a comprehensive metacognitive model and to implement behavioural strategies in order to improve their performance in the exercise. Thus, results suggest that children were able to improve their metacognitive knowledge and in this way strengthen their cognitive control mechanisms.

It is possible that the metacognitive scaffolding impacts more on the discrimination abilities because it was designed to help children to detect and extract task relevant features in order to produce strategies to improve their performance during training exercises. The effect of this metacognitive component may be related to the increase in d' indexes and in the underlying brain structures that are related to cognitive control mechanisms. Here, behavioural results revealed that in contrast to the NF and AC groups, children in the MF group where able to maintain their self-regulation abilities at the post-training session indicated by the lack of reduction in the SAE index. A possible explanation for these results is that MF training may promote regulation and monitoring abilities in order to implement strategies to improve performance. Thus helping children to become more aware of their actions and to implement the necessary compensatory strategies (i.e. be less impulsive after a mistake) would help them to commit fewer mistakes.

Vygotsky suggested that children´s development of higher cognitive functions can be supported by scaffolding and improved by the instrumental use of language (Bodrova et al., 2011; Luria, 2002; Vygotsky, 1978a, 1978b). Moreover, Efklides suggested that metacognitive knowledge can be transmitted and improved through social interaction by means of language. Our investigation presented thus suggests a possible internalization of the metacognitive strategy by the children, which may promote the generalization of its application into different contexts and tasks than the ones that where trained. Our electrophysiological data may indicate that MF training did result in a learning experience that influenced underlying brain structures. Follow up assessment and further research its needed in order to investigate the relation between MF, learning and the plasticity of brain structures that support it.

4.4.5 Conclusion

Taken together, and in line with previous studies from our group (Rueda et al., 2012; Rueda, Rothbart, et al., 2005), our results suggest that the influence of cognitive training in pre-school age children is similar to that of development, providing evidence that training interventions may actually act as a scaffolding supporting the emergence of cognitive control mechanisms and the maturation of underlying brain structures. Furthermore, our study provides evidence on the importance of designing cognitive interventions that include a metacognitive component that is transmitted trough a dynamic educative interaction.

5 Chapter

General Discussion

5. General Discussion

Throughout our life, we face situations that require the implementation of skilful self-regulation abilities in order to achieve our goals and hence to have a more satisfying life experience. A great effort has been done from different research traditions to understand the relation between cognitive mechanisms and self-regulation abilities, as well as to outline their normal course of development. Evidence from different fields has shown that self-regulation relates to cognitive control processes, such as executive attention and executive function (Posner & Rothbart, 2000; Rothbart & Rueda, 2005; Rothbart, Sheese, Rueda, & Posner, 2011). These processes emerge during infancy and show a protracted development throughout childhood until late adolescence. It has been suggested that the efficiency of this processes is a reliable predictor of general well-being, physical health, social competence and school achievement (Checa & Rueda, 2011; Moffitt et al., 2011).

Therefore, having a thorough understanding of the development of efficient self-regulation it's a very important enterprise. Thus, the main motivation behind the work done for this dissertation has been to contribute with research-based information to the characterization of the development of attention networks. A second goal was to study whether efficiency of attentional processes can be enhanced with training during development. I hope that this work might be helpful to inform the design of educational tools and interventions aimed at supporting the development and strengthening of self-regulation mechanisms in children.

In the past decade, the growing interest on brain research and the great advances in neuroimaging has contributed to enriching our understanding of how the brain works. At the same time, there has been a growing interest on understanding the implications that this information may have for children's education. Bruer (1997) suggested that the "bridge" between Neuroscience and Education was quite too far, meaning that knowledge was not yet enough to be able to translate understanding of how the brain works into knowledge that can inform educational practice. However, he also suggested that Cognitive Psychology could help fulfiling this gap (Bruer, 1997). More recently, Posner and Rothbart (2005) and Goswami (2006) have suggested that one mayor contribution of Cognitive Neuroscience to the field of Education relates to understanding the nature of cognitive mechanisms and neural networks underlying learning of school subjects (e.g. reading, numeracy, etc.). Another aspect that can be informed by Developmental Cognitive Neuroscience is related to individual differences affecting learning processes and the skills relevant for adequate self-regulation. Also, by understanding the influence produced by nature (e. g. genes and temperament) and nurture (e. g. environment and education) on the efficiency of cognitive processes it is possible to assess the possibility to improve the efficiency of such mechanisms.

In the past decades, there has been a growing effort to study the developmental trajectory of different cognitive functions, and changes on brain processes that underlie this development. The evidence gathered has contributed to the characterization of normative developmental trajectories of cognitive control processes, which in turn inform our understanding of "how" and "why" deficiencies on these processes lead to different pathologies (e.g. ADHD, dyslexia, etc). This knowledge can be a beneficial contribution to education because of its usefulness for designing efficient interventions aiming at improving these abilities (Goswami, 2006; Posner & Rothbart, 2005).

Thus, the studies presented in the present dissertation have two main goals. First, we conducted a series of experiments aiming to characterize the developmental trajectory of attention networks and their interactions during childhood. We were interested in the typical development of the three attention networks included in the Posner's neurocognitive model of attention (Petersen & Posner, 2012; Posner & Boies, 1971; Posner & Petersen, 1990). Also, we were interested in assessing the dynamical interactions that occurs between the different attention functions and the possible changes of these interactions with age. This research will increase our understanding about the normal developmental course of attention and support the design and implementation of our attention-training program.

Second, we were interested in evaluating the beneficial influence of experiential/educational factors on the efficiency of cognitive control processes. Thus, we conducted a study assessing the impact of an attention-training program on executive attention networks in pre-school aged children. Moreover, we assessed the impact produced by implementing the training with and without social metacognitive scaffolding.

It has been suggested that metacognitive control and cognitive control mechanisms are similar processes which share a number of underlying brain structures (Fernandez-duque et al., 2000b; Shimamura, 2000, 2008). Also, it has been indicated that metacognitive knowledge and metacognitive control are processes that interact whit each other, and that this interplay helps to produce more effective cognitive and behavioural regulation (Corno, 1986; Efklides, 2008). Metacognitive knowledge is continuously updated and enriched by observing the results of one’s own and other people’s actions, becoming aware of our metacognitive experiences, as well as by interacting and communicating with others (Efklides, 2008; Salonen et al., 2005). For that reason, language and social interactions are important factors that promote the emergence and enhancement of metacognitive knowledge.

Therefore, we designed a strategy-based intervention based on social scaffolding aimed to foster metacognitive knowledge, and we were able to examine the benefit of including this coaching component on a process-based attention-training program. We evaluate the near and far transfer effects of the training program, and compare the differential impact of training strategy by mean of behavioural and brain activation data.

In this last chapter, I will further discuss the results of our research and its implications for Psychology, developmental research and Education. Finally, I will also discuss on the limitations of the research presented in this dissertation as well as possible future research directions.

5.1 Attention: development, dynamics and interrelation with higher order processes

In the first study, we conducted two experiments with a modified version of the ANT task in order to examine the developmental trajectory of the attention networks and their interaction throughout childhood. We modify the child-friendly version of the ANT task used by Rueda et al. (2004) following the changes introduced by Callejas, et al. (2004). We included an invalid orienting cue in order to improve the measurement of the orienting network. Also, we included a warning auditory cue in order to separate the warning cue from the spatial cue to be able to measure the interaction between alerting and orienting networks.

Results from our first experimental series indicate that including an invalid orienting cue, and thus increasing to some degree the difficulty of the task, the developmental pattern of the orienting and executive attention evidence a more protracted development than was found in previous research (Rueda, et al., 2004). Also, our results shows a significant decline of the alerting score between the younger (6 -7 years) and the older groups (8 – 12 years), suggesting that younger children had more difficulties to maintain optimal levels of tonic alertness in absence of warning cues. Moreover, we found that the influence of the warning cues on the executive score for accuracy was modulated by age. Accuracy of younger children benefited more from the warning cue, while older children show a reduction in accuracy after a warning cue (similar to adults). Taken together these results indicate that throughout childhood there is a continuous development and refinement of mechanisms in charge of top-down attention control implicated in the maintenance of alertness, the disengagement and reorienting of attention, and conflict resolution.

The importance of understanding brain networks is to be able to elucidate their role in human behaviour. Our research provides information helping to further our knowledge of the development of the three attention networks described by Posner's model (Petersen & Posner, 2012; Posner & Boies, 1971).

Having a more precise understanding of network's development would support the research that tries to link genetic differences with actual behaviour. Our data indicates that the influence of alerting on executive attention its modulated by age. Previous studies have shown that phasic and tonic alertness is related to activity in the locus coeruleous that it's the source of norepinephrine (for reviews see Aston-Jones & Cohen, 2005). Also, evidence has shown distinct involvement of brain hemisphere, where rapidly acting events are left lateralized while more slowly changing states involve right hemisphere activity (Fan, McCandliss, Fossella, Flombaum, & Posner, 2005; Posner & Petersen, 1990). Therefore, further research is needed to understand how does hemispheric specialization develops throughout childhood and how it influences the executive attention network. Also, is important to research how the activity of the norepinephrine system influence the alerting network throughout childhood, what is its role in the interaction between the alerting and executive attention network, and what it's the relation with conditions like ADHD.

Evidence from neuroimaging studies suggests that during childhood higher cognitive functions requires a wide engagement of cortical areas (B J Casey et al., 2005; D. A. Fair et al., 2009; Power et al., 2010). This pattern of activation becomes more focalized as the system matures, indicating that the improvement in effectiveness of cognitive control is supported by increase specialization of underlying brain structures. Also there is evidence indicating that during infancy there are changes in axonal density and myelination (Gao et al., 2009). However, there is still more research needed to understand how this gradient of specialization changes on white matter and on brain connectivity impacts the efficiency and interactions of attention networks during childhood. The task presented in the first experimental series may provide useful paradigm to address the above mention questions.

The information discussed so far supports our understanding of the normal development of the attention networks and the activation of underlying brain structures related to executive attention in pre-school aged children. With this knowledge is possible to have a better understanding of the effects of experience on the efficiency of attention processes and the plasticity of underlying brain structures

5.2 Plasticity of executive attention network

The second main goal of this thesis was to examine the influence of experience over the efficiency of executive attention in pre-school aged children. To accomplish this goal we conducted a study where we evaluated near and far transfer effects of an attention-training program on behavioural and electrophysiological measures related to executive attention processes. Moreover, we examined whether including metacognitive scaffolding during training with our previously designed process-based program, what we called strategy-based training, would increase generalization of benefits to other domains.

The strategy-based intervention was conceived with the goal of fostering metacognitive knowledge. We designed an interactive scaffolding intervention based on Vygotsky's theory of influence of social interaction on cognitive development (Bodrova et al., 2011; Luria, 2002; Vygotsky, 1978a). In this way, we emulate an educational environment in order to evaluate the impact of integrating the computerized attention-training program with an educational intervention.

5.2.1 Cognitive plasticity: Near and far-transfer effects of training and differential effects related to training strategy

Our research group has conducted previous studies on the influence of process-based attention training on the efficiency of processes related to executive attention in preschool-aged children (Rueda et al., 2012; Rueda, Rothbart, et al., 2005). On behavioural measures, these studies show far-transfer effects of training to measures of fluid intelligence. However, no transfer effects were found on behavioural measures related to cognitive control or self-regulation (Rueda et al., 2012; 2005). Similarly, other studies have reported far-transfer effects to measures of intelligence after training in working memory (Jaeggi et al., 2008, 2011a), non-verbal reasoning (Bergman et al., 2011) and task-switching (Karbach & Kray, 2009; Karbach, 2008). However, currently there is an open debate regarding transfer effects of cognitive training into measures of intelligence. Some studies failed to replicated transfer into intelligence measures (Chooi & Thompson, 2012; Colom et al., 2010, 2013; Owen et al., 2010; Redick et al., 2013) and suggests that the cognitive training does not increase in fluid intelligence at the construct level.

Our results provide further evidence that may shed light into different aspects that may contribute to understand far-transfer effects into reasoning skills. Replicating previous findings (Rueda et al., 2012; Rueda, Rothbart, et al., 2005), behavioural results shows far-transfer effects to fluid intelligence and near-transfer into measures of inhibitory control. Interestingly, while there was no difference on the effect of training strategy intervention on measures of inhibitory control, we found larger gains on fluid-IQ measures for the group trained with the metacognitive scaffolding. Moreover, when we divide experimental groups into high and low pre-training scores, results show that regardless of training strategy similar gains are detected for the lower pre-training scores sub-group. However, gains for high pre-training scores sub-group were detected only for the metacognitive training group.

Tang and Posner (2014) suggest that training interventions may be divided in two general domains. Training brain networks involves the strengthening of a specific network by practice of a task that engage the network, while training brain state uses practice to develop a brain state that may influence the operation of many networks (Tang & Posner, 2009; 2014). Our process-based training program is clearly network training because it’s based on tasks that engage the executive attention network, however, we believe that the strategy-based metacognitive intervention may produce effects similar to the state training interventions.

The strategy-based intervention aimed to improve children’s ability to generate metacognitive models and enriched their metacognitive knowledge by means of interactive scaffolding. We expected that scaffolding would result in a learning process allowing children to internalize these skills in order to apply them to different contexts. Our design do not allow us to assert that there was learning process due to the lack of measures to assess resulting learning, However, data of training performance shows that the group trained with the metacognitive scaffolding committed less amount of errors and needed less trials to complete the training. Due to the design of our training, these results suggest the possibility that children learned strategies to improve their metacognitive knowledge, which helps them to improve their performance during training.

It is possible that that children trained with the metacognitive scaffolding may have learned to apply a cognitive strategy to enrich their MK (i.e. increase ability to generate metacognitive models). Internalizing this strategy may have influenced the activity of different networks, producing similar effects to state training. Thus, resulting in increase generalization of training effects into other tasks and contexts such as solving matrices in the fluid IQ test, which would lead to increase scores in untrained fluid-IQ tasks.

Further research is needed in order to clarify the way in which metacognitive knowledge may influence networks underlying cognitive processes. In order to clarify why the metacognitive scaffolding produce enhance transfer into fluid-IQ, further research is needed to evaluate how does metacognitive models improve the efficiency of cognitive processes?, how does metacognitive models shapes the activity of brain networks?, does learning and internalizing the ability to generate metacognitive models results in state changes of brain activity?, this learning results in plasticity of cognitive networks?. Maybe, the answer to these questions may provide further information on the neurocognitive effects of learning and development.

5.2.2 Brain plasticity: Influence of training on electrophysiological mechanisms and the differential effects related to training strategy

A limited number of studies have examined the effects of cognitive training on the ERPs related to cognitive control. Previous studies conducted with pre-school aged children have shown that the effect of training is similar to that of maturation (Rueda et al. 2004; 2012). Results of these studies indicate that ERPs related to conflict monitoring (N2/N450) show faster latencies following training, with a more adult-like dorsal-frontal topographic distribution in the scalp. Moreover, it has been shown that the influence of training on brain activation is sustained two-months later without further training (Rueda et al., 2012). Our results supports these findings by showing a similar effect on latency and topographical distribution of ERPs related to conflict monitoring and inhibitory control.

Rueda et al. (2005), conducted a study in which they examine the effects of an attention training program with a group of 4 and 6 years old. Comparing our results with those reported in this study is interesting to notice that, while the effect of training in process-based training group are similar to the effect of training in 4 year-olds, results of our strategy-based training group are similar to the results of the trained 6 years-old. As the 6 years-old group in the study by Rueda et al. (2005), our metacognitive scaffolding group presented a more posterior distribution of the N450 effect post-training, suggesting a more adult-like underlying activation (Rueda et al., 2012). This result supports the idea that metacognitive knowledge boosts the efficiency of cognitive control mechanisms by producing a more adult-like pattern of activation of the network related to conflict monitoring processes.

Also, our results show that the influence of metacognitive training on intelligence measures is supported by plasticity of brain mechanisms related to conflict monitoring. We found that observed gains in intelligence were related to an increase of the difference waveform area. Previous studies have suggested that both executive functions and the processes related to G share a common network of brain areas specially related to prefrontal structures (Duncan, Emslie, Williams, Johnson, & Freer, 1996; Duncan & Owen, 2000; Hampshire et al., 2012, 2011). These results may provide further evidence showing that the metacognitive scaffolding produce changes in the state of brain activity. A study using fMRI to examine the effects of working memory training shows that increase of brain activity was correlated with WM performance (Olesen et al., 2004), indicating that increase activity could be related to learning and not merely to increased effort needed in more difficult tasks (Klingberg, 2010). Therefore, is possible that the increase engagement of frontal areas after the strategy-based training is produced by a change in the state activity of the executive attention network. This change in brain state may be induced by the increase ability to integrate metacognitive knowledge and cognitive control mechanisms.

Also, results of attention training into inhibitory control processes provide further evidence supporting the findings that metacognitive scaffolding is more efficient in influencing brain network plasticity. We found that strategy-based training influences the latency of the components related to conflict monitoring (N2) and Inhibitory control (P3). It also produced an increase of the difference waveform area in the P3 component, that was related to the improvements in d' (i.e. an index of discrimination between conditions and proper behaviour adjustments to those conditions) and behavioural regulation (SAE). Previous studies have shown that brain networks training (Takeuchi et al., 2010) and brain state training (Y.-Y. Tang, Lu, Fan, Yang, & Posner, 2012) produce changes brain connectivity measure by diffusion tensor imaging (DTI). Results suggest that training intervention may produce changes in axonal density and myelination influencing white matter efficiency. It may be possible that the influence of the metacognitive scaffolding produced changes in brain network connectivity, resulting in faster engagement and better behavioural regulation.

In sum, electrophysiological data indicate that including metacognitive scaffolding boost the effects of attention training. The neural mechanisms underlying metacognitive effects are largely unknown, due to the lack of understanding about the specific influence that metacognitive knowledge produced in cognitive processes. However, our results provide information that may direct future research in order to understand how the interplay between metacognition knowledge and cognitive control processes may shape brain networks dynamics.

The construct of metacognitive knowledge has been largely used in the education research tradition, however to our knowledge it has not been explored in cognitive neuroscience. Our results support the important interplay between metacognitive knowledge and cognitive control for efficient self-regulation abilities

5.3 Future directions

The work presented here has open many questions regarding the relation between cognitive control, language, metacognitive knowledge and development of self-regulation.

Our study supports the important interplay between language, MK and cognitive control processes. However the effects produced by the interplay between this elements in brain networks is still largely unknown. Vygotsky (1978) suggested that a milestone in the development of higher order cognitive processes happens when children discover the instrumental use of language. Vygotskians argue that language can be an instrumental tool helping us to manipulate abstractly our environment and cognition (Bodrova et al., 2011; Luria, 2002; Vygotsky, 1978a). Supporting this suggestion, results from the present dissertation indicate that by enriching MK through language, it is possible to improve the efficiency of cognitive control mechanisms and brain state activity. However, what is the mechanism that links MK and cognitive control?

In the working memory model presented by Baddeley (2003), it was suggested that the phonological loop its and important aspect of working memory that allows to hold on memory traces before they fade away, and also articulatory rehearsal processes.. Some studies have suggested the important relation between, cognitive control and the phonological loop by presenting evidence that indicates how articulatory suppression impairs performance on task switching (Baddeley, Chincotta, & Adlam, 2001), on the Wisconsin Card Sorting Test (Dunbar & Sussman, 1995) and on reasoning (Farmer, Berman, & Fletcher, 1986). Therefore, it may be possible that the influence that MK produces in cognitive control may be related to the maintenance of a task metacognitive model on working memory, which informs cognitive control via the phonological loop. Further research its necessary to understand the nature of metacognitive models and how they influence the efficiency of cognitive control?, what are the mechanisms by which this relation happens?, does Metacognitive models are domain-specific (i.e. cognitive processes), or can they be applied to several domains (e.g. affective, social)?, how does metacognitive knowledge influence the dynamic of neural networks related to cognitive control?, how does MK influence the activity of the cingulo-opercular network (stable set-maintenance) and the fronto-parietal network (adaptive control)?. These are only few of the questions that can be pursued in order to clarify the relation between metacognitive knowledge and cognitive control mechanisms.

Our electrophysiological data shows that children trained with the metacognitive intervention show similar pattern of activation to the trained 6 years old in Rueda study (2005). This result may suggest that the ability to integrate MK and cognitive control mechanisms may account for some of the differences in efficiency of cognitive control throughout development. Therefore, is important to examine the differences on the ability to create, modify and use metacognitive models between adults and children. Also, is important to investigate how age-related differences on efficiency of cognitive control processes can be accounted by MK abilities. And what is the influence of MK on the maturation and dynamic of underlying brain structures.

Also, it is important to understand what is the influence of social interaction in the development and improvement of self-regulation. Our results suggest that training interventions that implicate social-interaction produce enhancement of training effects. Also, Kuhl, Tsao, & Liu (2003) conducted a study where they evaluate which conditions may prevent the declining of the ability to discriminate foreign-language phonetic units in infants. Their results suggests that exposure to a foreign-language is more effective when includes recorded social interactions (Kuhl et al., 2003). Also, vygotskian argues that is through social interaction that children discovers the importance of language as a instrumental tool and obtain the necessary scaffolding to develop higher order reasoning skills. Therefore, its important to further our research about how social relations influence the development, enhancement and efficiency of self-regulation. One important question is to examine if there is any transmission of metacognitive models between people?, if there is, how is it that internalizing a metacognitive model may influence our perception and self-regulation?, is it possible that metacognitive models only refers to cognitive processes or are they also related to social rules and cultural beliefs?. Further research its important to clarify the role of social interaction in the development of higher order processes

5.4 Concluding Remarks

By combining the frameworks of cognitive control and metacognition, the work done in the present dissertation suggests that in the present the "bridge" between neuroscience and education may be smaller. The big effort done to elucidate children's development has provided information that allows a better understanding of the influence produced by constitutional, environmental and experiential factors. Also, research on brain plasticity is providing evidence that supports the possibility that we can increase our potential. This idea has been alive in eastern contemplative traditions since many centuries ago. However, in the western research tradition this idea has been largely promoted by the emergence of neuroimaging techniques.

The possibility to increase our cognitive potential has implications in many aspects of life. Increasing self-regulation abilities by means of mindfulness meditation produce beneficial effects on wellbeing (Brown & Ryan, 2003; Wallace & Shapiro, 2006), cognitive control (Moore et al., 2012; Yi-Yuan Tang et al., 2007), immune system (Jacobs et al., 2011) and in stress reduction (Kabat-zinn, 2003; Kieviet-stijnen, Visser, Garssen, & Hudig, 2008).

Several authors has recently pointed out that countries should learn how to capitalize from their citizens cognitive resources both economically and socially (Beddington et al., 2008). Therefore, the educational systems must be optimized in order to be able to implement the necessary interventions in order to support the emergence of self-regulation and higher order cognitive processes. It is very important that educational policies are informed by research-based knowledge about how to design and implement education programs for different age groups.

The work done in this dissertation contributes to the large effort done in order translate the knowledge produce by developmental cognitive neuroscience into an application that may produce further benefits to education and children. It supports the beneficial relation between the research fields of developmental psychology, cognitive psychology, education and neuroscience. My whish is that this effort may continue and may bring more benefit to future generations.

In the words of one of the most important Tbetan Buddhist teachers alive today, H.H. Karmapa Trinley Thaye Dorje:

“*The inner wealth is our mind, our consciousness. I believe that this mind is like a wish-fulfilling jewel. If you know how to utilise this mind, it can produce the most* *beneficial effects. The best way to utilise and develop this mind is to absorb knowledge, and the most important kind of knowledge is the one that makes us a kind person, a decent person, a person worthy of respect. And the qualities which make an individual kind, decent, respectable are qualities such as patience, generosity, kindness. The good news is that we do not have to adopt or create these qualities, since they already potentially there in all of us.” The huffington post (http://www.huffingtonpost.co.uk/his-holiness-karmapa-thaye-dorje/the-wealth-of-europe_b_1608903.html)*

6 Chapter

Resumen en español

6.1 Introducción

A lo largo de nuestra vida nos enfrentamos a situaciones que requieren la aplicación de habilidades de auto-regulación para que logremos alcanzar nuestros objetivos y podamos experimentar una vida más satisfactoria. Distintas tradiciones de investigación se han dedicado estudiar la relación entre la auto-regulación y los mecanismos de control cognitivo, así como el curso normal de desarrollo de estos procesos. Evidencia recabada desde distintos campos de investigación han demostrado que la auto-regulación esta relacionada con procesos cognitivos como la atención ejecutiva o las funciones ejecutivas (A. Diamond, 2013; Rueda, Posner, et al., 2005). Dichos procesos surgen durante los primero años de vida y se desarrollan a través de la niñez, alcanzando la madurez alrededor de la adolescencia. La eficiencia de dichos procesos de auto-regulación es una medida que predice de forma confiable el bienestar en general, la salud física y las competencias sociales (Moffitt et al., 2011).

En la década pasada, el estudio de las bases cerebrales de la cognición, aunado con los avances en la tecnología de las técnicas de neuroimagen, ha aportado importante información ayudándonos a entender y enriquecer nuestro conocimiento de dichos procesos cognitivos y la dinámica cerebral subyacente a estos. Así mismo existe un creciente interés de la posibilidad que esta información pueda tener implicaciones para la educación de los niños. Bruer (1997) sugirió que existe un “puente” muy largo entre la neurociencia y la educación. De esta forma argumentaba la dificultad que existía de traducir los conocimientos acerca del funcionamiento de las neuronas y la sinapsis, en información relevante que pudiera guiar los esfuerzos en educación. Sin embargo, sugirió la posibilidad de que la psicología cognitiva sirva como posible mediador para acercar dichas tradiciones. Recientemente, Posner y Rothbart (2005) y Goswami (2006) sugirieron que una de las mayores contribuciones que puede hacer la neurociencia cognitiva a la educación es el proveer de información que ayude a entender la naturaleza de los mecanismos cognitivos y los sistemas neuronales que subyacen las habilidades requeridas para un optimo aprendizaje (p.e. la atención, lectura, el calculo). Esta información ayuda a entender las posibles diferencias individuales, así como la influencia que puede tener la naturaleza (genética) y el medio ambiente (las interacciones sociales o la educación) en el desarrollo y la eficacia de dichos procesos cognitivos.

Varios estudios se han llevado a cabo para caracterizar el curso del desarrollo de los diferentes procesos cognitivos, así como también de los respectivos cambios neuronales que subyacen la maduración de dichos procesos. Estos estudios han contribuido a la caracterización del curso natural de desarrollo de los procesos de control cognitivo, ayudándonos a entender el "Por qué" y el "Cómo" las deficiencias en estos procesos tienen como resultado problemas cognitivos (p.e. dislexia, ADHD). Este conocimiento puede beneficiar a la educación a través de proporcionar información que permita un entendimiento más profundo de estos procesos, de esta manera puede apoyar el desarrollo de intervenciones más eficaces, buscando mejorar las deficiencias y hacer más eficientes dichos procesos (Goswami, 2006; Posner & Rothbart, 2005).

Siguiendo esta línea, los estudios presentados en esta tesis doctoral tienen como objetivo, primero, realizar estudios que permitan mejorar nuestro conocimiento acerca del desarrollo normal de las redes atencionales y sus interacciones durante la niñez. Principalmente, nuestro interés se enfoca en el desarrollo natural de las tres redes atencionales descritas en el modelo neurocognitivo de Michael Posner (Petersen & Posner, 2012; Posner & Boies, 1971; Posner & Petersen, 1990). De la misma manera, estamos interesados en la interacción dinámica que existe entre dichas redes. Esta información nos ayudará a mejorar nuestro conocimiento acerca del curso normal de desarrollo de las redes atencionales, así como también de los cambios en las interacciones que son influenciados por la edad. La información recabada nos apoyará en el diseño, implementación y evaluación de los efectos de nuestro programa de entrenamiento de la atención.

Segundo, estamos interesados en evaluar la influencia que tiene los factores medio ambientales en la eficiencia y el desarrollo de los procesos atencionales en niños de edad pre-escolar. Por esta razón llevamos a cabo un estudio en el que evaluamos el impacto de un programa de entrenamiento de la atención (Rueda et al., 2005; 2012) en los procesos relacionados con la red de atención ejecutiva con una muestra de niños de edad pre-escolar. De la misma manera, quisimos evaluar la diferencia que produce el entrenamiento cuando se implementa con un programa de andamiaje metacognitivo y cuando se implementa sin el dicho andamiaje. Para evaluar los efectos de transferencia cercana y lejana utilizamos medidas de electroencefalografía y comportamentales (i.e. inteligencia, control inhibitorio, memoria de trabajo). A continuación se describen los resultados de dichos estudios.

6.2 Desarrollo de la atención y sus interacciones durante la niñez

Estudios anteriores utilizaron una versión de la tarea ANT original (Attention Network Task por sus siglas en ingles) modificada para ser aplicada en niños, con la finalidad de poder estudiar el curso normal de desarrollo de las redes atencionales durante la niñez (Rueda, et al., 2004). Los resultados de este estudio indican que: 1) la puntuación de alerta muestra una estabilidad durante la niñez, 2) no existen diferencias en la entre niños y adultos para la puntuación de la red de orientación, y 3) encontraron una disminución en al puntuación de la atención ejecutiva entre los 6 y los 7 años seguida por una estabilidad entre los 7 y los 10 años. Sin embargo, otros estudios evidenciaron un desarrollo continuo de la red de orientación y la red de atención ejecutiva cuando se utilizaron paradigmas que requieren una mayor implicación de los procesos de control (Fjell et al., 2012; Waszak et al., 2010).

Debido a esto, en el primer estudio presentado en esta tesis, evaluamos el desarrollo de las redes atencionales utilizando la tarea ANT modificándola siguiendo los mismos cambios hechos por Callejas et al. (2004). Dichos cambios incluyen: a) introducir una señal de alerta auditiva para diferenciarla de la señal visual de orientación, lo cual permite medir la interacción entre las redes de alerta y orientación; e b) incluir una señal de orientación invalida que nos permita medir los procesos de desenganche y reorientación de la atención, refinando así la medida de orientación.

Los resultados de este estudio indican una reducción de la puntuación de la red de alerta entre los 6 y 7 años, y una progresiva estabilidad entre los 8 y 12 años. Estos datos sugieren que el grupo de niños más pequeño presentan más dificultad en el mantenimiento de niveles óptimos en alerta tónica, lo que hace que se beneficien más de la señal de alerta. En relación a la red de orientación, los resultados indican que los niños más pequeños muestra mayores puntuaciones de orientación a comparación del resto de los niños lo cual sugiere una mejora en la reorientación de la atención durante la niñez. Replicando estudios previos (Fjell et al., 2012; Waszak et al., 2010) nuestros resultados muestra una reducción progresiva de la puntuación de conflicto con la edad, indicado que cuando se integra una condición que requiere el desenganche y reorientación de la atención la red de atención ejecutiva muestra un desarrollo más prologando durante la niñez.

Los datos de nuestro primer estudio muestran evidencia de las interacciones que han sido descritas en resultados previos (Callejas et al., 2005). Los resultados muestran mayores puntuaciones de orientación bajo condiciones de alerta, los cuales ha sido explicados como una aceleración de la orientación (Callejas et al., 2005), o como un incremento en la atención selectiva bajo condiciones de alerta (Fuentes & Campoy, 2008). Así mismo, encontramos una reducción del la puntuación de conflicto después de la señal de orientación válida, mientras que la señal de orientación invalida produce mayores puntuaciones de conflicto. Estos datos sugieren que la señal valida de orientación produce una facilitación del procesamiento de conflicto, sin embargo cuando el estímulo objetivo aparece al lado contrario de la señal de orientación se produce un proceso de desenganche y re-orientación de la atención, lo cual puede dejar menos recursos para la supresión de los estímulos distractores.

Estudios previos muestran que estados de mayor alerta producen menor eficiencia en los procesos de resolución de conflicto (Aston-Jones et al., 1999). Nuestros resultados muestran que la señal de alerta no afecta las puntuaciones de conflicto calculadas a partir de los tiempos de reacción. Sin embargo, cuando el efecto de conflicto se calcula con el porcentaje de aciertos, los datos muestran que los niños más pequeños (6-8 años) tiene un mayor efecto de interferencia en ausencia de una señal de alerta, mientras que los niños mayores o bien presentan patrones que muestran similar interferencia en ambas condiciones de alerta, o un patrón más parecido al encontrado en los adultos. Estos resultados sugieren que, mientras los niños más pequeños se ven beneficiados por una señal de alerta debido a la incapacidad de mantener niveles adecuados de alerta tónica, los niños mayores se ven perjudicados por dichas señales debido a que ya han desarrollado dicha habilidad.

Dado que la ANT es una tarea ampliamente usada en distintas disciplinas, nuestro resultados suponen una aportación tanto teórica como práctica en el estudio del desarrollo cognitivo. De esta manera, los hallazgos en este primer estudio proveen información útil para el diseño e implementación de programas de entrenamiento y/o intervención durante la infancia que tengan como objetivo impactar procesos atencionales y de control ejecutivo.

6.3 Entrenamiento de la atención

El segundo objetivo de esta tesis fue el de evaluar la influencia de un programa de entrenamiento de la atención en la eficiencia de los procesos de la atención ejecutiva en niños de edad pre-escolar. Para eso llevamos a cabo una serie de estudios en los que estábamos interesados en replicar y extender los resultados encontrados por Rueda y Cols (2005, 2012) así como también evaluar la potenciación de los efectos del entrenamiento a través del andamiaje metacognitivo. Para eso ampliamos el programa de entrenamiento utilizado por Rueda y cols (2005, 2012) introduciendo nuevos ejercicios, aumentando el número de sesiones, así como introduciendo la estrategia de entrenamiento con andamiaje metacognitivo. Para poder medir los efectos de transferencia lejana y cercana del entrenamiento utilizamos medidas comportamentales de inteligencia, memoria de trabajo y control inhibitorio, así como también el análisis de los potenciales evocados corticales asociados a los procesos de monitorización del conflicto y control inhibitorio.

Replicando estudios previos (Rueda, et al. 2005; 2012), los resultados comportamentales demuestran efectos de transferencia a medidas de control inhibitorio y a medidas de inteligencia fluida. Los datos muestran que ambos grupos muestran mejoras similares en las medias de control inhibitorio, sin embargo la ganancia en las medidas de inteligencia fluida son mayores para el grupo de entrenamiento con el andamiaje metacognitivo. Posiblemente la transferencia del efecto del entrenamiento en medidas de inteligencia sea debido a que 1) ambos procesos comparten estructuras subyacentes (Duncan, 2000; Hampshire et al., 2012), así como también a 2) la relación jerárquica que existe entre estos procesos (Demetriou et al., 2008).

Para evaluar los efectos del entrenamiento en procesos de monitorización y resolución de conflicto se utilizó una tarea de flancos adaptada para niños (Purificación Checa et al., 2014), analizando el efecto en medidas de activación cerebral a través de los potenciales corticales evocados (ERP´s por sus siglas en ingles) asociados a la monitorización del conflicto (N2/N450) (Abundis-Gutiérrez et al., 2014; Botvinick et al., 2001). Similar al estudio de Rueda et al. (2005) nuestros datos muestran que el entrenamiento influye la activación cerebral de manera similar al desarrollo. Los resultados muestran que los niños entrenados sin el andamiaje metacognitivo presentan patrones de activación similar a los del grupo de 4 años entrenados en el estudio de Rueda, indicando una activación más anterior de la respuesta neural al conflicto (medida a través de la diferencia en amplitud entre la condición congruente e incongruente). Sin embargo, los entrenados con el andamiaje metacognitivo presentan una activación cerebral similar a los del grupo de niños entrenados de 6 años en el estudio de Rueda, reflejado por una distribución topográfica más posterior asemejando a una activación más adulta. Así mismo los datos apoyan a los resultados de transferencia a medidas de inteligencia fluida, indicando que a mayor ganancia en amplitud de la N2/N450 mayor ganancia en la puntuación de inteligencia solo para los niños entrenados con el andamiaje metacognitivo.

Para medir los efectos del programa en procesos de control inhibitorio se utilizó una tarea de Go-NoGo adaptada para niños. Se evaluó la influencia del entrenamiento en medidas comportamentales de discriminación (d’) y regulación conductual (SAE), así como en medidas de ERP´s asociados a la monitorización del conflicto (N2/N450) (Jonkman, Sniedt, & Kemner, 2007) y al control inhibitorio (P3) (Polich, 2007). Los resultado indican que la mejora en la eficiencia de la red de la atención ejecutiva se ve principalmente reflejada en la latencia de la detección del conflicto (N2/N450) y de la activación de los procesos asociados al control inhibitorio (P3). Así mismo, nuestros datos muestran que los niños entrenados con el andamiaje metacognitivo presentan mejoras significativas en: 1) los índices de d’, 2) reducción de la latencia del N2 y P3, 3) una relación entre el incremento del índice de d’ y la reducción de la latencia en P3, 4) una relación entre el incremento de d’ y el incremento del área de la P3.

Los resultados de este estudio tienen implicaciones importantes para el campo educativo ya que muestran que con una intervención relativamente corta (15 sesiones) se puede influir en la eficiencia de procesos de control cognitivo necesarios para el aprendizaje. Así mismo, los datos proveen información empírica que muestra como la interacción entre metacognición y control cognitivo mejora la eficiencia de dichos procesos. A nivel comportamental esta influencia se traduce en una mejor capacidad intelectual, así como también en la capacidad de discriminación y regulación comportamental. A nivel de activación cerebral, esta mejora se refleja en una activación cerebral más “madura” con patrones que asemejan a los presentados por los adultos, mostrando que el entrenamiento produce una influencia similar a la del desarrollo.

6.4 Conclusiones

- La neurociencia cognitiva puede aportar información que permita un mejor entendimiento de las capacidades cognitivas, del curso de desarrollo normal de dichas capacidades, de las posibles problemas que resultan en deficiencias cognitivas, así como también ayudando al desarrollo de intervenciones que permitan, no solo apaliar esas deficiencias, sino que también mejorar la eficiencia de los procesos.
- La capacidad de mantener la alerta tónica presenta un importante desarrollo durante la edad escolar. Mientras los niños más pequeños (6 – 8 años) se ven beneficiados por la presentación de una señal de alerta, los niños más grandes se ven perjudicados con la presentación de una señal de alerta debido a que poseen una mejor capacidad de mantenimiento de la alerta tónica.

- La red de orientación no muestra señales de mejora durante el desarrollo cuando se utilizan tareas que la orientación exógena a estímulos. Sin embargo, la red de orientación muestra un desarrollo prolongado de la capacidad de desenganche y re-orientación, capacidades que requieren un mayor control endógeno.
- De la misma manera, cuando se aumenta la carga de control a través de incluir una señal de orientación invalida, la red de atención ejecutiva muestra un desarrollo más prolongado debido a que es posible que los procesos de desenganche y re-orientación de la atención eviten que queden los suficientes recursos disponibles para evitar la interferencia de los flancos.
- Los datos muestran la presencia de interacción entre las redes durante la niñez. Los resultados muestran que la eficacia de la atención ejecutiva se ve facilitada con una señal de orientación válida, mientras que la señal invalida produce un mayor conflicto.
- Así mismo, los datos muestran que bajo condiciones de alerta, la orientación de la atención se ve facilitada, posiblemente por una aceleración de la orientación o por una facilitación de la atención selectiva.
- Los datos de nuestro estudio muestran que el efecto de la alerta sobre la eficiencia del procesamiento de conflicto se ve modulada por la edad. Mientras que la eficacia de la resolución del conflicto en los niños más pequeños se ven beneficiados por la presentación de una señal de alerta, la eficacia de los niños más grandes se ven perjudicada. Esto puede ser asociado a una menor capacidad de mantenimiento de niveles óptimos de la alerta tónica en los niños más pequeños.
- La eficacia de los procesos asociados a la atención ejecutiva son susceptibles a la mejora a través del entrenamiento y de las influencias del medio ambiente, tales como la interacción social.

- El entrenamiento en funciones de control cognitivo produce mejoras en medidas de inteligencia fluida, especialmente cuando el entrenamiento incluye un andamiaje metacognitivo enfocado en mejorar el conocimiento metacognitivo. Dichas mejoras puedes ser producidas debido a que: 1) los procesos de control cognitivo y de inteligencia comparten estructuras cerebrales subyacentes, o 2) debido a que los mecanismos de control cognitivo son procesos en los que se sustentan los procesos cognitivos superiores medidos en las escalas de inteligencia.
- El entrenamiento cognitivo influencia los procesos de monitorización del conflicto produciendo efectos similares a los del desarrollo. Dicha influencia produce un modificación de los patrones de activación cerebral de manera que reflejen patrones más maduros especialmente para niños que fueron entrenados con el andamiaje metacognitivo. De la misma manera, dicho efecto en la activación cerebral se ve asociado al incremento en las puntuaciones de inteligencia, aportando evidencia que apoya la relación entre los procesos de control cognitivo y los procesos cognitivos superiores medidos por los test de inteligencia.
- El entrenamiento de la atención produce mejoras en índices comportamentales de discriminación y de regulación de la conducta, solamente en niños entrenados con el andamiaje metacognitivo. Así mismo, el entrenamiento acelera la activación cerebral de los procesos cognitivos asociados a la monitorización de conflicto y el control inhibitorio. Dicha aceleración esta relacionada a la mejora comportamental en los índices de discriminación y regulación conductual, solamente para los niños entrenados con el andamiaje metacognitivo.
- Estos datos presentan evidencia que apoyan la importancia que tienen la interrelación entre el control cognitivo y el conocimiento metacognitivo para una eficiente regulación de la cognición y la conducta.

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Appendix

Universidad de Granada

Manual de Acompañamiento Metacognitivo para los juegos de entrenamiento de la Atención

LNC

Laboratorio de Neurociencia

Cognitiva del Desarrollo

Acompañamiento Metacognitivo

Como parte del acompañamiento que los entrenadores/profesores deben de dar a los estudiantes durante la ejecución de los juegos den entrenamiento en la atención, está el componente de dialogo metacognitivo. El "dialogo Metacognitivo" es un dialogo que se establece entre entrenador y estudiante con la finalidad de desarrollar una mayor autoconciencia de la ejecución de las tareas. Dicha autoconciencia potencia la capacidad de auto-monitoreo, que a su vez resulta en mayor capacidad de aplicar los mecanismos de control en las situaciones que lo requieren.

Siguiendo la lógica de la Interacción Mediacional, el entrenador debe de establecer un dialogo con el estudiante, con el que se busca que el estudiante adquiera mayor nivel de monitorización de sus acciones. El entrenador debe de ser capaz de utilizar un dialogo de retroalimentación-reflexiva, a través del cual reflexionara conjuntamente con el estudiante, acerca de las acciones realizadas, a la vez que le proporciona retroalimentación de los resultados de sus acciones. A través de dicha retroalimentación, el estudiante será más conciente de las acciones realizadas, los efectos de sus acciones, que errores se cometieron, que acciones fueron efectivas, etc.

A continuación se presenta una serie de diálogos metacognitivos adaptados a cada una de los juegos a realizar. El dialogo es una guía para el entrenador, sin embargo, dicho dialogo puede y debe de ser adaptad

ESQUEMA GENERAL

Sesión	Ejercicios
1.	1. Hierba 2. Paraguas 6. Laberinto 4. Estanque
2.	13. Rana: alerta 5. Estanque invisible 7. Retratos
3.	8. Retratos con demora Pre-números 10. Números 11. Stroop
4.	13. Rana: alerta 12. Granja Pre- números 14. Stroop de cuatro números
5.	15. Formas 13. Rana: alerta/ completar (ejercicios nº 1,2,4,5,6) 16. Cambio
6.	Completar… (Stroop/Cambio/Granja)

Sesión 1

Juego 1: Hierba

En este juego, el niño usa el joystick para dirigir a un gato que es un dibujo animado. La tarea consiste en llevar al gato al césped que hay en los lados de la pantalla. En niveles más avanzados, una gran cantidad de césped se convierte en barro. Al gato solo le gusta jugar en el césped y no en el barro, así que el niño debe llevar al gato hacia el césped y no hacia el barro. Cuando el niño completa correctamente un ensayo por llevar al gato hacia el césped, el gato sonríe y baila. Si se lleva al gato hacia el barro, o no lo mueve de su posición dentro de un periodo limitado de tiempo, entonces no se completa el ensayo correctamente y el gato frunce el ceño.

El juego 1 tiene 7 niveles. Se requieren 3 ensayos consecutivos correctos para avanzar de un nivel al siguiente.

Procedimiento para explicar el juego:

Entrenador: Este es el Gato, y este es el mando con el que jugaras. Si mueves el mando para este lado (indicar al sujeto que mueva el joystick para la derecha) que sucede?.

Sujeto: El gato se mueve para la derecha.

Entrenador: Muy bien!... y ahora que sucede cuando mueves el joystick al otro lado (indicar que mueva el joystick a la izquierda).

Sujeto: el gato se mueve para la izquierda.

Entrenador: Entonces dime que tengo que hacer para que el gato se mueva a donde yo quiero que Vaya?

Sujeto: tienes que mover el joystick para donde quieras que Vaya el gato…

Entrenador: muy bien!... ahora prueba mover el gato hacia todas las direcciones para que veas todos los lugares a los que se mueve el gato…. (Dar un tiempo para que el niño mueva el gato por la pantalla del juego)….bueno ahora te cuento en que consiste el juego.

Al gato le gusta jugar en el césped, Y como ves en las orillas de la pantalla hay césped. Que crees que es lo que quiere hacer el Gato?.....

Sujeto: el gato quiere ir a jugar al césped (o una respuesta similar).

Entrenador: exactamente!... el gato es muy juguetón y por eso quiere ir a jugar al césped. Anda has que vaya al césped. (Dejar que el sujeto mueva el gato al césped)…. Muy bien, has visto que se pone muy contento!!... vale pues entonces lo que tenemos que hacer es que el gato este contento durante el juego… y para que se ponga contento que tenemos que hacer?...

Sujeto: hacer que juegue en el césped (respuesta deseada, si no da una respuesta similar volverle a repetir el objetivo).

Entrenador: una cosa más… el gato es bastante juguetón, y le gusta llegar rápido al césped… así que trata de ser lo más rápido en llevar al gato al césped para que juegue…. Qué crees que pasará si no eres rápido en ayudar al gato?....

Sujeto: pues que el gato se enfadará, molestará, etc…

Nivel 2

Entrenador: muy bien!... pues eso es lo que tenemos que hacer… llevarlo al césped para que esté contento. Anda hazlo….(ahora esperar que el sujete realice el juego hasta que cambie de nivel, cuando cambie de nivel y aparezca por primera vez el barro continuar con)…. Muy bien hecho!!... has visto que ha pasado en la pantalla??....

Sujeto: si… ahora tiene una parte marrón!...

Entrenador: asi es!!.... pues te cuento que esa parte es barro, y a este gato no le gusta el barro!... así que tenemos que seguir haciendo lo que hemos hecho hasta ahora… y que es lo que hemos hecho hasta ahora???...

Sujeto: hemos hecho que el gato llegue al césped… (o alguna respuesta similar).

Entrenador: exactamente… pero quiero que veas que sucede cuando el gato no va al césped… haz que llegue al césped… que ha sucedido??..

Sujeto: el gato se ha enojado (esta triste, está molesto., etc)…

Entrenador: vez el barro no le gusta al gato…. Así que llevémoslo a la grama para que esté contento…

- Si el niño lo hace fuera de tiempo:

Entrenador: Oh!has visto que ha pasado?....

<u>Sujeto:</u> Al gato se le acabo el tiempo.

<u>Entrenador:</u> entonces que tienes que hacer?...

<u>Sujeto:</u> ser más rápido…

<u>Entrenador:</u> muy bien!... Vamos inténtalo de nuevo, y esta vez, ¡trata de llevar al Gato hacia el césped lo más rápido que puedas!

Nivel 3

<u>Entrenador:</u> oye y ahora que ha pasado con el barro??...

<u>Sujeto:</u> ahora hay más barro en la pantalla!... (o respuesta similar).

<u>Entrenador:</u> vale pues entonces ahora tenemos que tener más cuidado…. De ahora en adelante, esto pasara cada vez más… es decir…. Ira habiendo cada vez más barro así que trata de tener cuidado…

Notas:

- *Es importante que se haga una reflexión al niño cada momento que realice un error. Por ejemplo:*

Que ha pasado ahora?... por qué ha sucedido este error?... que puedes hacer para hacerlo mejor?..

- *Así mismo* Si el niño lo hace fuera de tiempo:

<u>Entrenador:</u> Oh! has visto que ha pasado?....

<u>Sujeto:</u> Al gato se le acabo el tiempo.

<u>Entrenador:</u> entonces que tienes que hacer?...

<u>Sujeto:</u> ser más rápido…

<u>Entrenador:</u> muy bien!... Vamos inténtalo de nuevo, y esta vez, ¡trata de llevar al Gato hacia el césped lo más rápido que puedas!

- Preguntas frecuentes que pueden realizar los niños:

“¿Por qué no le gusta al gato ir hacia el barro?”

Porque no le gusta ensuciarse. Vamos a llevarlo al césped para que pueda jugar.

“¿Cómo lo hago? No sé cómo hacerlo”

Los niños piden ayuda con frecuencia cuando el césped está cerca de la esquina.

Hmm.. Vamos a pensar en esto. ¿Cómo podemos llevar al gato al césped sin meterlo en el barro?

Si ellos siguen necesitando ayuda:

Bien, vamos a tratar de ir muy despacito hacia el césped.

Si ellos persisten en ir hacia el barro:

Oh, cuando este yendo hacia el barro, ¡asegúrate de parar! ¿Qué podemos hacer para ir al césped?

Juego 2: Cazar

En este juego, los niños de nuevo usan el joystrick para dirigir al gato. En este juego aparece un paraguas rosa que se mueve por la pantalla. La tarea del niño es dirigir al gato para que coja el paraguas, simplemente haciendo que el dibujo del gato toque el dibujo del paraguas. (Cada ensayo comienza cuando el niño mueve el joystrick). En los niveles posteriores, el paraguas se mueve más rápido.

El juego 2 tiene 7 niveles. Se requieren 3 ensayos consecutivos correctos para avanzar de un nivel al siguiente.

Si la velocidad del juego disminuye durante el juego, por favor mira la nota sobre la velocidad de los juegos al final del punto 2.

Procedimiento para explicar el juego:

Entrenador*: Pues mira quien está de nuevo con nosotros… es el Gato con el que jugamos anteriormente. En este juego, tu también controlas al gato como en el juego anterior. Bueno pues ahora te cuento como es este juego. En este juego lo que ha pasado es que el gato a perdido a su amigo "el paraguas". Y en el jardín del gato llueve mucho, y al gato no le gusta mojarse. Así como no le gusta el barro, tampoco le gusta mojarse. Pero este paraguas no es un paraguas normal. Sino que es un paraguas muy travieso, le gusta jugar con el gato y por eso huye de él. Lo que tienes que hacer es que el gato coja el paraguas por si comienza a llover. Qué crees que tienes que hacer para que el gato coja el paraguas?*

<u>Sujeto:</u> *Tengo que hacer que le gato corra detrás del paraguas. (si la respuesta no es similar o no sabe la respuesta, ayudarle con preguntas reflexivas para que el niño encuentre la respuesta, como por ejemplo: que haces tú cuando quieres atrapar a alguien que huye de ti?)…*

<u>Entrenador:</u> *Muy bien!... Hazlo, comienza a perseguir al paraguas. Cuando haya atrapado al paraguas continuar con…. Has visto lo que ha sucedido?... que ha pasado con el paraguas cuando lo atrapas?.*

<u>Sujeto:</u> *el paraguas se ha abierto.*

<u>Entrenador:</u> *Exacto!... eso es lo que sucede cuando el gato atrapa el paraguas. Continuemos… por que el paraguas quiere seguir jugando con el gato… recuerda que tienes que hacer que el gato atrape al paraguas lo más rápido que pueda.*

Nivel 2 y subsiguientes

En los niveles superiores, tanto la velocidad del gato como la del paraguas aumentan. Por lo que el acompañamiento debe de ir enfocado en la detección de dicho cambio, y las subsecuentes reflexiones para ayudar al niño a adaptarse y desarrollar estrategias para conseguir el objetivo.

<u>Entrenador:</u> *(cuando el niño falle en atrapar al paraguas) oye he visto que no has podido coger al paraguas ahora... por qué crees que pasa esto?*

<u>Sujeto:</u> *si… no he podido cogerlo por que el paraguas se mueve más rápido...*

<u>Entrenador:</u> *así es!!....cada vez que el gato coge al paraguas, el paraguas comienza a correr más rápido para que no lo cojan… que crees que tiene que hacer el gato para coger al paraguas?*

<u>Sujeto:</u> *Lo tengo que mover más rápido… (o alguna respuesta similar).*

<u>Entrenador:</u> *Haber hazlo… (si en dado caso el niño logra coger al paraguas continuar con: muy bien!, continua así)….*

(si en dado caso no consigue atrapar al paraguas: ves que no has podido atrapar el paraguas por que crees que pasa esto?

<u>Sujeto:</u> *es que el gato corre muy rápido…*

<u>Entrenador:</u> *Vale, si es así entonces que tienes que hacer tu?... recuerda que tu controlas al gato.*

<u>Sujeto:</u> *entonces tengo que hacerlo más despacio yo?...*

Entrenador: exactamente, si tu controlas al gato, el gato hará lo que tú le digas que haga con el joystick…. Así que si quieres que el gato no corra tanto, que tienes que hacer?

Sujeto: tengo que mover más despacio el joystick?..

Entrenador: así es!... prueba hacerlo…

- Si el niño lo hace fuera de tiempo:

Entrenador: Oh! has visto que ha pasado?....

Sujeto: Al gato se le acabo el tiempo.

Entrenador: entonces que tienes que hacer?...

Sujeto: ser más rápido…

Entrenador: muy bien!... Vamos inténtalo de nuevo, y esta vez, ¡trata de llevar al Gato hacia el césped lo más rápido que puedas!

Juego 6. Laberinto

En este juego, los niños utilizan el joystick para llevar al gato a través de un laberinto. La tarea del niño consiste en coger la "Comida de Gato", en un tiempo limitado.

El laberinto consiste en unas líneas negras que el gato no puede traspasar. (Las líneas simplemente impiden el movimiento del gato en esa dirección). En niveles posteriores, el laberinto se va haciendo más complejo.

El juego 6 tiene 7 niveles. Se requieren 3 ensayos consecutivos correctos para avanzar de un nivel al siguiente.

Procedimiento para explicar el juego.

Entrenador: Ahora Cómo el gato ha corrido y jugado mucho, ahora le ha dado mucha hambre. Así que vamos a darle de comer algo de comida para gatos… ¿Ves comida para gato por aquí?

Sujeto: si allí esta una lata de comida para gato…

Entrenador: vale pues entonces lo que tienes que hacer que es?..

Sujeto: llevar al gato hacia la comida…

Entrenador: muy bien!!...pero te quiero preguntar una cosa antes de comenzar, ves las líneas negras que están a los lados del gato?.... qué crees que son?

Sujeto: si contesta son muros, una calle o algo similar… continuar con: así es, son unos muros que no permiten que el gato se salga, o salte sobre de ellos…

- *si el sujeto contesta "no se"… decirle, mueve el gato hacia las líneas negras y veremos qué pasa… E: cuando lo haga preguntarle "has visto que ha sucedido"… S: no ha podido pasar… E: exactamente, estos muros no dejan que el gato pase… así que trata de mantener al gato dentro de los muros…. Y continuar con…*

Entrenador: vamos a llevar al gato a la comida para que no tenga más hambre…

Nivel 2 y subsiguientes

En los niveles subsiguientes la complejidad del laberinto irá aumentando. Por lo que se deberá ir haciendo el acompañamiento dependiendo del rendimiento del niño. Siempre haciendo preguntas reflexivas que hagan al niño ser consciente de las nuevas condiciones que se le presentan, y que ajustes debe de realizar para adaptarse a dichas condiciones.

Por ejemplo:

- Si el niño intenta mover al gato hacia la línea, o preguntar sobre ellas:

Entrenador: Detente… recuerdas que son las líneas negras?

Sujeto: son muros…

Entrenador: y que pasa si el gato quiere pasar a través del muro?

Sujeto: El gato no puede ir a través de la línea negra porque esas líneas son como muros

Entrenador: Muy bien, entonces que es lo que tienes que hacer?

Sujeto: seguir el camino que hacen los muros…. O respuesta similar.

Al final de la Sesión: Guau!!!¡Muy bien! ¡Eres un campeón en estos juegos! El próximo día, también vamos a jugar a algunos juegos muy divertidos. Conoceréis al Pato, que es el mejor amigo del Gato. ¡Y será muy divertido!

Sesión 2

Nota: al comenzar cada juego, recuerda mover el cursor fuera de la pantalla.

¿Recuerdas cuando jugamos al juego con el Gato el otro día?

Bien, pues hoy, vamos a conocer al mejor amigo del Gato,¡ su amigo Pato! Te voy a ensañar los juegos:

Juego 4. Estanque

En este juego los niños controlan al gato. La tarea del niño es mover al gato para que persiga al pato, para ello simplemente el gato tiene que tocar al pato, antes de que se acabe el tiempo para el ensayo. El pato puede nadar en el lago que aparece en el centro de la pantalla, mientras que el gato no. Sin embargo, el pato siempre se mueve en línea recta y los niños pueden anticipar por donde saldrá el pato del lago. Así mismo, podrán dirigir al gato, para que coja al pato, cuando éste deje el lago. En niveles posteriores, el pato se moverá más rápidamente.

El juego 4 tiene 7 niveles. Se requieren 3 ensayos consecutivos correctos para avanzar de un nivel al siguiente.

Si la velocidad del juego decrece durante el juego, por favor mira la nota sobre la velocidad de los juegos al final del punto 2.

Procedimiento para explicar el juego.

Entrenador: Mira a quien tenemos de nuevo…. Es el gato con el que jugamos el día anterior, lo recuerdas?... bien pues ahora no solo tendremos al gato, sino que también estará otro de los amigos del gato que es “el pato”. En este juego, el gato está jugando al “pilla pilla” con el Pato. Tu sabes que tiene que hacer el gato?...

Sujeto: claro… el gato tiene que pillar al pato…

Entrenador: muy bien!... es parecido al juego con el paraguas… solo que ahora tenemos un obstáculo… que crees que es lo que aparece en el centro de la pantalla?...

Sujeto: Parece un lago…

Entrenador: eso es!... es un lago… pues te cuento que como a todos los patos… a este pato le gusta el agua y puede nadar…. Pero el gato no le gusta mojarse, por que no sabe nadar… por eso es que el gato no puede entrar en el lago… que crees que tiene que hacer el gato para pillar al pato, cuando el pato entra en el agua?....

Sujeto: esperar a que salga del agua!...

Entrenador: pues si… el gato tiene que esperar a que el pato salga del agua para poder pillarlo… ahora te diré un secreto…. Cuando el pato entra al agua, solo puede nadar en línea recta!... sabes que es una línea recta?...

Sujeto: si, es así (debe de indicar como es una línea recta… sino, el entrenador debe de mostrarle como es una línea recta diciendo: esta es una línea recta)…

Entrenador: vale, pues entonces así es como nada el pato… solo puede nadar en línea recta… sabiendo este secreto, que crees que tiene que hacer el gato cuando el pato se mete al agua?...

Sujeto: creo que el gato se debe de poner del otro lado del lago… (si responde no se… ayudarle a través de decirle: si el pato entra aquí en el lago, indicarle al sujeto la dirección del pato en la pantalla y decirle, en donde debería de estar el gato entonces?

Entrenador: muy bien… entonces comencemos el juego!... recuerda que tienes que ser lo más rápido que puedas.

Nivel 2 y subsiguientes

En los niveles superiores la velocidad del pato irá aumentando. Es importante hacérselo notar al niño, para que pueda realizar los ajustes correspondientes para realizar la tarea. Mantener el acompañamiento metacogntivo, realizando preguntas reflexivas cuando el niño tenga preguntas o realice algún error.

Entrenador: ahora el juego se va a poner un poco más difícil, porque el pato va a correr y nadar más rápido…. Así que el gato tiene que ser más rápido si quiere pillar al pato… y que otra cosa tiene que hacer el gato para pillar al pato, cuando este se mete al agua?...

Sujeto: el gato tiene que estar del otro lado del lago… (si responde no se, preguntar: que ha hecho el gato hasta ahora?...)

Entrenador: exactamente… sigue como lo has hecho hasta ahora…

Preguntas frecuentes:

¿Por qué el Pato no coge al Gato?

Porque en este juego que están jugando, el Gato siempre coge al Pato.

¿Por qué el Gato no puede ir al agua?

Porque este Gato no sabe nadar.

¿Cómo puedo hacerlo? No sé cómo hacerlo.

Vamos a pensar un poco sobre esto. El pato puede meterse en el agua, pero el Gato no. ¿Cómo podemos coger al Pato? (regresar al dialogo reflexivo del nivel 1).

Juego 13 Rana

En este juego la tarea del niño consiste en cazar moscas. Hay una rana que caza las moscas, las cuales están dentro de un bote. Para cazarlas el niño debe presionar la barra espaciadora. Se ha de indicar a los niños que han de estar muy atentos a cuando sale la mosca para que la rana pueda cazarla. En algunos ensayos la salida de la moscas está precedida por un tono. Tenemos que decirle al niño que unas veces aparecerá el tono y otras no, pero que ellos deben darle a la barra cuando la mosca salga del bote y no cuando escuchen el tono. Hay seis niveles diferentes, que manualmente habrá que cambiar al iniciar el nuevo nivel.

Nivel 1.

Catch time: 1200

Min. Wait time: 2.000 mlsg

Max. Wait time: 4.000

Nivel 2

Catch time: 1.200

Min. Wait time: 2.000 mlsg

Max. Wait time:6000.

Nivel 3

Catch time: 900

Min. Wait time: 2.000 mlsg

Max. Wait time:6.000

Nivel 4

Catch time: 900

Min. Wait time: 2.000 mlsg

Max. Wait time: 8.000

Nivel 5

Catch time: 600

Min. Wait time: 2.000 mlsg

Max. Wait time: 8.000

Nivel 6

Catch time: 600

Min. Wait time: 2.000 mlsg

Max. Wait time:10.000

Procedimiento para explicar el juego.

Entrenador: Pues ahora haremos un juego diferente…. En este juego tenemos que ayudar a esta ranita a que pueda comer por que tiene mucha hambre… tu sabes que comen las ranitas?...

Sujeto: comen insectos…(si responde no se decir: pues te cuento que las ranas comen moscas)..

Entrenador: pues en este juego tenemos que ayudar a la rana a comer las moscas que ves en este jarrón… Alguna ves has tratado de pillar una mosca?...

Sujeto: si (si contesta afirmativo comenzar la siguiente frase con: entonces como has visto… en dado caso conteste negativo, comenzar la siguiente frase con: bueno pues te cuento que …)

Entrenador: …. Las moscas son muy rápidas, por eso tu también tienes que ser muy rápido para ayudar a la rana a que pille las moscas…. Para eso tienes que pulsar la barra espaciadora en cuanto veas que una mosca sale del jarrón… sabes cual es la barra espaciadora?..

Sujeto: si es esta …. (de recibir respuesta negativa, indicar cual es la barra espaciadora)..

Entrenador: vale pues recuerda que tienes que ser lo más rápido posible… ahora tu sabes si las moscas hacen algún ruido?.. que ruido hacen las moscas?...

Sujeto: debe de indicar algún sonido….

Entrenador: bien!, ese es el sonido de las moscas… pero dime una cosa, las moscas hacen ese sonido siempre?... o solo a veces lo puedes escuchar?..

Sujeto: solamente a veces hacen el sonido…

Entrenador: así es!!... en este juego también pasa lo mismo, algunas moscas hacen ruido y algunas no… así que tienes que prestar mucha atención para ver cuando la mosca sale… algunas harán ruido y otras no… así que tienes que estar muy atento… que tienes que hacer cuando la mosca salga?...

Sujeto: tengo que presionar la barra… (si en dado caso no se recuerda, volver a indicar las instrucciones).

Entrenador: muy bien!... entonces estás listo para comenzar….

- Si presiona la barra cuando escucha el sonido:

<u>Entrenador:</u> *tienes que esperar a que salga la mosca...las moscas no salen cuando suena el ruidito, así que tienes que estar atento a cuando sale la mosca.*

Niveles 2 y subsiguientes

En los niveles superiores, la velocidad de las moscas aumenta, así como también el intervalo de tiempo que deben de esperar los niños para que salga la siguiente mosca es mayor. Por lo tanto se debe de indicar a los niños que deben de prestar más atención para que puedan caputrar a las moscas.

<u>Entrenador:</u> ahora en los siguientes niveles tienes que estar más atento… ahora las moscas ya saben que la rana esta allí…. Así que ahora serán más rápidas cuando salen, y algunas también pueden tardarse más en salir… así que mantente muy atento…

- Cuando el niño cometa un fallo, remarcarlo con dialogo reflexivo, por ejemplo: se te ha escapado la mosca!... por que se te escapo?... porque no la capturaste?... porque presionaste la barra antes de que saliera la mosca?...

Juego 5. Estanque invisible

Este juego es idéntico al juego 4 (El estanque) excepto que el pato ahora desaparece y no lo podemos ver cuando nada a través del lago.

El juego 5 tiene 7 niveles. Se requieren 3 ensayos consecutivos correctos para avanzar de un nivel al siguiente.

Si la velocidad del juego decrece durante el juego, por favor mira la nota sobre la velocidad de los juegos al final del punto 2.

Procedimiento para explicar el juego.

<u>Entrenador:</u> te acuerdas de este juego?... lo hicimos antes del juego de la rana… te acuerdas que teníamos que hacer?...

<u>Sujeto:</u> si, el gato tiene que pillar al pato…

<u>Entrenador</u>: exactamente!... el gato tiene que pillar al Pato… y te acuerdas de las reglas?... que pasaba con el pato y que pasaba con el gato?...

<u>Sujeto:</u> el pato se mete al lago para nadar y escapar del gato… y el gato no puede nadar, asi que no se mete al lago…

<u>Entrenador:</u> muy bien!... y te acuerdas como nadaba el pato?... en qué dirección nadaba el pato?...

<u>Sujeto:</u> el pato nadaba en línea recta (de ser similar la respuesta, decir: así es!.. continuar con el punto siguiente….)

En caso de no recordarlo: continuar con: recuerdas que el pato solo podía nadar en línea recta?... si vale pues… continuar con el siguiente punto

<u>Entrenador:</u> vale pues ahora el pato es más listo… y ha aprendido a nadar sumergido… entonces no lo veremos cuando se meta al agua!... pero nosotros sabemos algo de el… sabemos cómo nada no?... en qué dirección nada?

<u>Sujeto:</u> nada en línea recta!..

<u>Entrenador:</u> así es… así que aunque no lo veamos sabemos dónde va a aparecer… así que donde tiene que estar el gato?...

<u>Sujeto:</u> del otro lado del lago….

<u>Entrenador:</u> muy bien!... venga, vamos a jugar… recuerda que tienes que ser lo más rápido que puedas!...

Niveles 2 y subsiguientes

En los niveles superiores la velocidad del pato irá aumentando. Es importante hacérselo notar al niño, para que pueda realizar los ajustes correspondientes para realizar la tarea. Mantener el acompañamiento metacogntivo, realizando preguntas reflexivas cuando el niño tenga preguntas o realice algún error.

<u>Entrenador:</u> ahora el juego se va a poner un poco más difícil, porque el pato va a correr y nadar más rápido…. Así que el gato tiene que ser más rápido si quiere pillar al pato… y que otra cosa tiene que hacer el gato para pillar al pato, cuando este se mete al agua?...

<u>Sujeto:</u> el gato tiene que estar del otro lado del lago… (si responde no se, preguntar: que ha hecho el gato hasta ahora?...)

<u>Entrenador:</u> exactamente… sigue como lo has hecho hasta ahora…

<u>Preguntas frecuentes:</u>

¿Por qué el Pato no coge al Gato?

Porque en este juego que están jugando, el Gato siempre coge al Pato.

¿Por qué el Gato no puede ir al agua?

Porque este Gato no sabe nadar.

¿Cómo puedo hacerlo? No sé cómo hacerlo.

Vamos a pensar un poco sobre esto. El pato puede meterse en el agua, pero el Gato no. ¿Cómo podemos coger al Pato? (regresar al dialogo reflexivo del nivel 1).

Al final:

Guau!!!¡Muy bien! ¡Eres un campeón en estos juegos! El próximo día, también vamos a jugar a algunos juegos muy divertido.

SESIÓN 3.

Nota: al comenzar cada juego, recuerda mover el cursor fuera de la pantalla.

¿Recuerdas estos juegos de ordenador a los que jugaste la última vez? Bien. ¡Pues hoy vamos a jugar a más juegos divertidos!

Juego 7- Retratos

Este juego está compuesto por parejas de dibujos. Los niños usan un joystick y un botón del joystick para manipular el cursor.

En cada ensayo, el niño primero hace clic en un recuadro naranja que hay en el centro de la pantalla. Esto hace que aparezca un dibujo en una de las esquinas de la pantalla. El niño hace clic en el dibujo que ha aparecido. El recuadro naranja entonces se abre y deja ver dos dibujos diferentes. El niño debe hacer clic en el dibujo que sea igual que el que hay en la esquina.

El dibujo puede diferir: en el animal que represente, en el color del fondo, en el color del borde, en la orientación de las líneas en el borde, o en características dentro del dibujo del animal.

En los primeros niveles, el dibujo difiere en múltiples aspectos, pero en niveles posteriores, los dibujos solo se diferencian en una característica. Si el niño hace clic en el dibujo correcto, las manos aplauden y el aplauso se escucha. Si el niño hace clic en un dibujo equivocado, un sonido "Oh, oh" se escucha.

El juego 7 tiene 7 niveles. Se requieren 3 ensayos consecutivos correctos para avanzar de un nivel al siguiente.

Si la velocidad del juego decrece durante el juego, por favor mira la nota sobre la velocidad de los juegos al final del punto 2.

Procedimiento para explicar el juego.

<u>Entrenador:</u> Bueno ahora haremos otro juego distinto…Para comenzar el juego debes hacer un click en la pantalla… hazlo, veamos que pasa….

<u>Sujeto:</u> aparece un cuadro naranja, y un dibujo de un animal!..

<u>Entrenador:</u> muy bien!...ahora, mira bien la imagen del animal… dime que tiene esa imagen… pero fijate bien en todos los detalles que tiene!...

- *En este punto es importante que el sujeto se de cuenta de los detalles del dibujo, es decir… el color del recuadro, las rallas blancas, la dirección de las rallas y el fondo de la figura…. En caso de que pase por alto alguno de los detalles, realizar preguntas de manera reflexiva, para que sean capaces de detectarlos…. Dicha detección es importante para el acompañamiento metacognitivo y el dialogo reflexivo en la detección de los errores… "si el niño no sabe en qué tiene que fijarse, como sabrá que comete un error"…*

<u>Sujeto:</u> tiene un recuadro de color azul (o rojo)...un animalito (oso, jirafa, serpiente..)… tiene unas líneas de color blanco….

<u>Entrenador:</u> señalar los detalles que haya olvidado… por ejemplo: muy bien!... pero también te falto decirme algo… de que color es el fondo del dibujo? … hacia donde van las líneas blancas?...

Sujeto: haaa… es que eso no lo vi… pues tiene fondo de color (amarillo o azul)… y las líneas van hacia la (izquierda o derecha)…

Entrenador: vale, muy bien!... quiero que te recuerdes que tienes que ver muy bien todos estos detalles, porque lo que tienes que hacer es ver cuál de las dos imágenes que veras aparecer después es exactamente igual que la que aparece en la esquina… Para poder ver las otras imágenes debes de hacer click en esa imagen…. Haber hazle click para que veamos las otras imágenes…. Ahora dime, cuál de estas imágenes es exactamente igual que la que esta en la esquina….

Sujeto: esta!...

Entrenador: vale muy bien!...dime porque razón son las mismas?

Sujeto: porque los colores del recuadro son los mismos!...

Entrenador: muy bien!... ahora dime en que otros detalles te tienes que fijar?.... recuerdas que los hemos dicho hace un rato?...(debe de recordar cada uno de los detalles, si no lo hace, señalarlos en la pantalla para que los vea y los pueda detectar)…

Sujeto: el color del recuadro, el fondo del dibujo y la dirección de las líneas blancas…

Entrenador: muy bien, recuerda que tienes que ponerle mucha atención a esos detalles para que veas cual es el que es idéntico…. Venga vamos a jugar!... dale a la figura que es igual!... haz visto lo que sucede!...

Sujeto: sii… me aplauden…

Entrenador: muy bien!... pues eso es por que lo has hecho bien… el programa te dirá si lo haces bien o lo haces mal… venga vamos a jugar!...

Con frecuencia los niños ponen su dedo en el botón e inadvertidamente hacer clic cuando ellos están moviéndose hacia el target. Esto da como resultado una respuesta incorrecta. Recuérdales que no pongan el dedo en el botón hasta que ellos necesiten hacerlo.

Entrenador: Ten cuidado de no hacer clic antes de tiempo.

Niveles 2 y subsiguientes

En los primeros tres niveles, los dibujos se diferencias en varias características, lo cual hace que la detección de las diferencias sea relativamente fácil. En los niveles superiores, la dificultad aumenta debido a que las diferencias comienzan a darse en un solo aspecto, y cada vez es más sutil. En los últimos niveles, ya las diferencias se dan en la *misma figura del animalito, por lo que hay que hacer que el niño ponga atención también a las diferencias en las imágenes.*

Cuando los niños cometan un error, dar acompañamiento con dialogo reflexivo, ayudando al niño a recordar las distintas dimensiones a las que tiene que prestar atención. Por ejemplo:

- *Sujeto: y ahora por que me salió mal?...*
- *Entrenador: ha de ser por que no prestaste atención bien al dibujo… recordemos que cosas son las que debes de ver para que veas las diferencias… dimelas… (ahora es importante no señalarlas, sino que el niño las enumere vervalmente… en dado caso olvide alguna decirle: oye pero te has olvidado de una… sabes cual es?... si en dado caso el niño no la recuerda recordarlo verbalmente…)*
- *En el momento en que las diferencias sean en los animales propiamente dichos (últimos niveles)… darle instrucciones para que también preste atención a dichos detalles. }*

Juego 8. Retratos con demora

Este juego es idéntico al juego anterior, excepto que el dibujo de la esquina ahora desaparece después de que el niño haga clic en él. El niño tiene recordar el dibujo antes de hacer clic en él, y posteriormente seleccionar el dibujo que es igual en el panel.

El juego 8 tiene 7 niveles. Se requieren 3 ensayos consecutivos correctos para avanzar de un nivel al siguiente.

Si la velocidad del juego decrece durante el juego, por favor mira la nota sobre la velocidad de los juegos al final del punto 2.

Procedimiento para explicar el juego.

Entrenador: bueno ahora haremos un juego igual al anterior… solo que con una diferencia!... haber haz lo mismo que en el anterior para que veas cual es la diferencia!...

Sujeto: ahora se desaparece la figura de la esquina…

Entrenador: eso es!... la diferencia es que ahora tienes que recordarte de la figura que has visto por que esta se desaparece!... y después tienes que decir cual de las que ves es igual a la que apareció en la esquina!...

Sujeto: pero eso será más difícil!..

Entrenador: si más difícil, pero más divertido también!... ahora tendrás que tener buena memoria!... haber si tienes buena memoria, dime que es a lo que le teníamos que prestar atención en el juego anterior?...

Sujeto: el recuadro, la dirección de las líneas, el color del fondo, y a la figura!.... (si el sujeto no lo recuerda, señalarle los elementos a los que hay que prestar atención.)

(Ayúdales hasta que puedan hacerlos por si solos).

Niveles 2 y subsiguientes

En los primeros tres niveles, los dibujos se diferencias en varias características, lo cual hace que la detección de las diferencias sea relativamente fácil. En los niveles superiores, la dificultad aumenta debido a que las diferencias comienzan a darse en un solo aspecto, y cada vez es más sutil. En los últimos niveles, ya las diferencias se dan en la misma figura del animalito, por lo que hay que hacer que el niño ponga atención también a las diferencias en las imágenes.

Cuando los niños cometan un error, dar acompañamiento con dialogo reflexivo, ayudando al niño a recordar las distintas dimensiones a las que tiene que prestar atención. Por ejemplo:

- *Sujeto: y ahora porque me salió mal?...*
- *Entrenador: ha de ser porque no prestaste atención bien al dibujo… recordemos que cosas son las que debes de ver para que veas las diferencias… dímelas… (ahora es importante no señalarlas, sino que el niño las enumere verbalmente… en dado caso olvide alguna decirle: oye pero te has olvidado de una… sabes cuál es?... si en dado caso el niño no la recuerda recordarlo verbalmente…)*
- *En el momento en que las diferencias sean en los animales propiamente dichos (últimos niveles)… darle instrucciones para que también preste atención a dichos detalles. }*

Al final:

Guau!!!¡Muy bien! ¡Eres un campeón en estos juegos! El próximo día, también vamos a jugar a algunos juegos muy divertido.

SESIÓN 4.

Pre- números. ¿En qué consiste?

Este “juego” se utiliza para que el niño se familiarice con la representación numérica de las cantidades, ya que en los siguientes juegos tendrá que utilizar dicho conocimiento. Para eso utilizamos una plantilla en la que ayudamos al niño a entender la correspondencia entre numero y conjunto de cosas.

Entrenador: el día de hoy haremos juegos en donde tendras que decirme el número de objetos que aparecen. … puedes decirme cuantos conejos hay aquí? (señalar el grupo de conejos en la plantilla)…

Sujeto: hay cuatro…

Entrenador: muy bien!!... ahora dime cuantos hay aquí … (continua hacia abajo en la hoja, haciendo la misma pregunta… y dando reforzamiento positivo al niño)…al finalizar continuar con… muy bien!... veo que eres muy apañao con los números… vale continuemos con el siguiente juego!....

- Nota: al comenzar cada juego, recuerda mover el cursor fuera de la pantalla.

Juego 10. Los números

Este juego requiere igualar cantidades numéricas. En cada ensayo, el niño usa el joystick para hacer clic en la caja gris en el centro de la pantalla.

Un conjunto de frutas (target) aparece en la pantalla durante un breve periodo de tiempo. Las frutas luego desaparecen, y dos nuevos conjuntos de frutas aparece.

La tarea de los niños es hacer clic en el conjunto con el mismo número de frutas que había en el conjunto target.

El juego 10 tiene 6 niveles. Se requieren 9 ensayos correctos para avanzar al nivel siguiente.

Procedimiento para explicar el juego.

<u>Entrenador:</u> Bien, ahora estamos listos para comenzar el juego… Primero, déjame que te muestre que tienes que hacer… Haz clic dentro del recuadro, dime que ves?

<u>Sujeto:</u> aparece una fruta y un número!..

<u>Entrenador:</u> muy bien… ¿Puedes contar cuantas manzanas hay aquí? (el sujeto debe de decir el número de frutas)... vale y dime el número que hay arriba... (debe de decir el número que aparece en la parte superior del cuadro)… Muy bien… ahora has otro click en el recuadro… ¿Cuál de estos es igual al de antes?.... has click en el que es igual que el de antes… muy bien!... eso es lo que tenemos que hacer, continua con el juego…

- *Si es necesario, repetir dicho dialogo en algunos ensayos más para estar seguros que el niño ha interiorizado las reglas.*

Niveles 2 y subsiguientes

En niveles posteriores, las posibilidades de elección son más parecidas entre sí, (por ej. 6 manzanas versus 5 manzanas, en lugar de 6 manzanas versus 1 manzana) y el conjunto de frutas expuesto para hacer la elección no siempre contiene el mismo tipo de frutas que el conjunto target. En los ensayos más difíciles, el conjunto correcto (esto es, el conjunto con el mismo número de frutas) es de un tipo de fruta diferente que el conjunto target, mientras que el conjunto incorrecto es del mismo tipo.

<u>Entrenador:</u> ahora al igual que en los juegos anteriores, este juego también se pondrá más difícil poco a poco… así que necesitas poner más atención…

- Cuando los sujetos realicen errores, deberá de realizarse un dialogo reflexivo enfocado en el error específico. Por ejemplo.

<u>Entrenador:</u> has cometido un error!... por qué crees que ha sido?..

<u>Sujeto:</u> no se, yo le he dado a las manzanas y me salió error!...

Entrenador: bueno como te he comentado ahora tienes que poner más atención… has visto que aparecen dos frutas distintas?...

Sujeto: si… y le he dado a la misma fruta!..

Entrenador: bueno pero recuerda que lo que tienes que hacer es ver el número de frutas…. No si la fruta es la misma o no…

- También puede ser que se equivoquen en la cuenta del número, en los niveles superiores. En este caso utilizar un dialogo reflexivo como por ejemplo:

  Entrenador: huy otro error… que crees que paso ahora?

  Sujeto: no se… es que ahora ya los dos grupos se parecen mucho!...

Entrenador: así es… ahora se va poniendo más difícil … así que hay que poner mucha atención en la cuenta de los números… recuerda que tiene que ser igual que el número de frutas que aparece al principio… pero no necesariamente tiene que ser la misma fruta…

Juego 11- Stroop

En cada ensayo de este juego, el niño primero hace clic en el recuadro verde.

Aparecen dos conjuntos de ítems y la tarea del niño es hacer clic en el conjunto que tenga más ítems. En los primeros ensayos, el conjunto simplemente contiene frutas. En los ensayos posteriores, los conjuntos contienen dígitos numéricos; el niño tiene que seleccionar correctamente el conjunto con más ítems sin tener en cuenta el valor de los números (ej. Un conjunto de seis “2” tiene más ítems que un conjunto de tres “9” incluso cuando el digito 9 tiene un valor mayor).

El juego 11 tiene 6 niveles. Se requieren 3 ensayos correctos para avanzar al nivel siguiente. Cuando empiezan los ensayos en los que aparecen los números, sólo los ensayos incongruentes (aquellos en los que el conjunto más grande contiene los números con el valor más pequeño) cuentan como ensayos correctos.

Procedimiento para explicar el juego

Entrenador: muy bien…. Ahora vamos a hacer un juego muy parecido al anterior, pero ahora lo que tienes que hacer es decir que conjunto de frutas o números es el que tiene más cantidad… tu veras aparecer en el cuadro, dos conjuntos de cosas, ya sean frutas o también números… pues lo que tienes que hacer es hacer un click en el conjunto que tenga más cantidad…. Por ejemplo: cuantos dedos tengo en esta mano (mostrar 2 dedos)… y en esta (mostrar con la otra mano 4 dedos)…..en que mano tengo la mayor cantidad de dedos???...

Sujeto: en la que tienes cuatro…

Entrenador: muy bien!... en la que tengo 4 tengo mayor cantidad de dedos…. Muy bien… pues lo mismo tienes que hacer aquí… me tienes que decir que grupo tiene la mayor cantidad… dime, que tenemos que hacer para saber que grupo tiene la mayor cantidad?...

Sujeto: tenemos que contar el número de frutas o números…

Entrenador: muy bien!... tenemos que contar el numero de frutas o números que hay en cada grupo… vale púes entonces vamos a continuar con el juego…

Niveles 2 y subsiguientes

En los niveles superiores la complejidad del juego aumenta a medida que se van mostrando grupos de objetos con número de ítems similares, grupos de ítems con números, y grupos de ítems que combinan ambos. Cuando se presentan grupos de números, es importante hacer al niño reflexionar que no es el valor del número lo que importa, sino que el número de Items que hay de ese mismo número. Así mismo, es importante hacer ver al niño que la posición de los ítems no tiene nada que ver con la cantidad de ítems presentada, recalcar que lo importante es que cuente la cantidad de ítems. Al momento que los niños cometan errores, recordar mantener un acompañamiento metacognitivo a través del diaologo reflexivo.

Cuando el niño cometa un error realizar dialogo relfexivo como el ejemplo siguiente:

- Si se confunde por la posición de ítems:

Sujeto: me di error… por que?

Entrenador: a que grupo de ítems le has dado?...

Sujeto: a este… (señalando el grupo que aparentemente tiene más… pero que por la forma de agruparlos parecen menos)..

Entrenador: y los has contado?...

Sujeto: no por que es el grupo en el que ha mas!...

Entrenador: haber estas seguro… contemos…. ves, a veces las cosas nos parecen más cuando en realidad no lo son… así que lo importante es… "Contar", no te olvides de prestar atención y contar bien…

- *Si se confunde por el valor de los números:*

Sujeto: me dio error!... pero si le di al número más grande!

Entrenador: pero contaste el número de números que había en el grupo?...

Sujeto: no porque el número era más grande!

Entrenador: bueno, pero recuerdas las instrucciones… (debe de responder: hacer click en el grupo que tenga mas ítems)… y tu diste click al grupo con el número más grande… pero no el que tenia más ítems... los habéis contado?...

Sujeto: no

Entrenador: vale pues ese fue el error…. Recuerda que tienes que contar los ítems…ponle atención al grupo de números, no al valor del número… venga, vamos a continuar, y recuerda contar bien!..

Al final:

Guau!!!¡Muy bien! ¡Eres un campeón en estos juegos! El próximo día, también vamos a jugar a algunos juegos muy divertido.

SESIÓN 5

Nota: al comenzar cada juego, recuerda mover el cursor fuera de la pantalla.

Hoy, vamos a continuar jugando algunos juegos divertidos en el ordenador. ¿Estás preparado?

Juego 12. La granja

En este juego, los niños tienen que meter a las ovejas dentro del corral mientras mantienen a los lobos fuera. En cada ensayo, el niño usa el joystick para hacer clic en el recuadro amarillo. El recuadro luego se mueve hacia los lados para que se vea a una oveja o a un lobo. Cuando la oveja aparece, el niño presiona el botón del joystick para poner a la oveja dentro del corral. Cuando el lobo aparece, sin embargo, el niño no debe presionar el botón (para que el lobo se quede fuera del corral). En niveles posteriores, el lobo aparece con un disfraz de oveja que hace que se parezca a una oveja.

El juego 12 tiene 6 ensayos, incluyendo un mínimo de al menos un ensayo con un lobo, se deben completar para avanzar al siguiente nivel.

Procedimiento para explicar el juego.

Entrenador: Bueno ahora haremos un juego distinto… En este juego, todas las ovejas del granjero José se han salido de su corral…. Lo que tú tienes que hacer es ayudar al granjero a poner todas las ovejas dentro del corral… pero ten cuidado, por que también hay un lobo que quiere meterse en el corral para comerse a las ovejas…. Así que asegúrate de meter solamente a las ovejas…. Los lobos se quedan afuera!...

Bien… para comenzar a jugar lo que tienes que hacer es hacer click sobre este montón de paja, que es donde se esconden los animales…. Allí mismo veras aparecer al animal… te puede aparecer una ovejita, o un lobo… que es lo que tenemos que hacer con las ovejitas?..

Sujeto: las tenemos que meter en el corral…

Entrenador: muy bien… solo las ovejas van en el corral… para meterlas en el corral, lo único que tienes que hacer click encima de la ovejita…. Así ella sabe que puede entrar en el corral… pero ten cuidado, recuerda que hay un lobo suelto por allí… así que cuando salga no hagas click, solo espera un rato y él se ira, si haces click el lobo entrara al corral y se llevará a todas las ovejitas… así que tienes que poner atención para que no dejes entrar a ningún lobo… así que, qué tienes que hacer para que las ovejitas entren en el corral?...

Sujeto: tengo que hacer click en la ovejita…

Entrenador: muy bien… tienes que hacer click en la ovejita… y que tienes que hacer cuando aparece el lobo?....

Sujeto: no tengo que hacer nada para que el lobo se valla…. (si el sujeto no responde, o no sabe… repetir las instrucciones…)

Entrenador: muy bien!!... eso es lo que tienes que hacer… venga vamos a jugar…

Niveles 2 y subsiguientes

En los niveles superiores, la frecuencia con que aparecen los lobos aumenta. Además, puede ser que los lobos estén disfrazados de oveja, dando un poco de complejidad a la tarea. Por lo que es importante que se haga reflexión a los niños acerca de esto para que puedan regular si estrategia.

- Si el sujeto comete errores, realizar dialogo reflexivo. Por ejemplo:

Sujeto: me equivoque de nuevo…

Entrenador: que ha pasado?... porque te equivocaste?

Sujeto: es que le di al lobo en lugar de a la oveja…

Entrenador: y porque paso eso?

Sujeto: es que le di muy rápido…

Entrenador: muy bien… pues entonces lo que tienes que hacer para no cometer más estos errores es poner mucha atención….

- Error por lobos disfrazados de oveja:

Sujeto: hay… ese era un lobo!!... pero por que estaba de oveja?-..

Entrenador: es que ese lobo es muy listo, y tienes que tener cuidado porque ahora sabe que solo dejas entrar a ovejitas, y por eso se ha disfrazado de oveja ahora… que tienes que hacer si aparece uno de estos lobos disfrazados de oveja?...

Sujeto: no tengo que hacer click, así se va…. (si no responde, realizar un dialogo reflexivo para que se dé cuenta que no hay diferencia entre el lobo, y el lobo disfrazado de oveja)

Entrenador: muy bien!... entonces ten mucho cuidado, porque ahora te pueden aparecer lobos disfrazados de ovejas… venga a poner mucha atención… sigue!...

Juego 13 Rana

En este juego la tarea del niño consiste en cazar moscas. Hay una rana que caza las moscas, las cuales están dentro de un bote. Para cazarlas el niño debe presionar la barra espaciadora. Se ha de indicar a los niños que han de estar muy atentos a cuando sale la mosca para que la rana pueda cazarla. En algunos ensayos la salida de la moscas está precedida por un tono. Tenemos que decirle al niño que unas veces aparecerá el tono y otras no, pero que ellos deben darle a la barra cuando la mosca salga del bote y no cuando escuchen el tono. Hay seis niveles diferentes, que manualmente habrá que cambiar al iniciar el nuevo nivel.

Nivel 1.

Catch time: 1200

Min. Wait time: 2.000 mlsg

Max. Wait time: 4.000

Nivel 2

Catch time: 1.200

Min. Wait time: 2.000 mlsg

Max. Wait time:6000.

Nivel 3

Catch time: 900

Min. Wait time: 2.000 mlsg

Max. Wait time:6.000

Nivel 4

Catch time: 900

Min. Wait time: 2.000 mlsg

Max. Wait time: 8.000

Nivel 5

Catch time: 600

Min. Wait time: 2.000 mlsg

Max. Wait time: 8.000

Nivel 6

Catch time: 600

Min. Wait time: 2.000 mlsg

Max. Wait time:10.000

Procedimiento para explicar el juego.

Entrenador: Te recuerdas de este juego?... ya lo habíamos jugado… cuéntame que es lo que tenemos que hacer?..

Sujeto: ayudar a que la ranita pueda comerse a las moscas…

Entrenador: bien y te acuerdas como hacíamos eso?...

Sujeto: teníamos que hacerlo con la barra espaciadora… (si en dado caso el sujeto no recuerda las instrucciones … Para eso tienes que pulsar la barra espaciadora en cuanto veas que una mosca sale del jarrón…)

Entrenador: vale pues recuerda que tienes que ser lo más rápido posible… ahora recuerdas si las moscas hacían algún ruido?.

Sujeto: debe de indicar el sonido….

Entrenador: bien!, ese es el sonido de las moscas… recuerda que tienes que prestar mucha atención para ver cuando la mosca sale… algunas harán ruido y otras no… así que tienes que estar muy atento… que tienes que hacer cuando la mosca salga?...

Sujeto: tengo que presionar la barra… (si en dado caso no se recuerda, volver a indicar las instrucciones).

Entrenador: muy bien!... entonces estás listo para comenzar….

- Si presiona la barra cuando escucha el sonido:

  Entrenador: tienes que esperar a que salga la mosca...las moscas no salen cuando suena el ruidito, así que tienes que estar atento a cuando sale la mosca.

Niveles 2 y subsiguientes

En los niveles superiores, la velocidad de las moscas aumenta, así como también el intervalo de tiempo que deben de esperar los niños para que salga la siguiente mosca es mayor. Por lo tanto se debe de indicar a los niños que deben de prestar más atención para que puedan caputrar a las moscas.

Entrenador: ahora en los siguientes niveles tienes que estar más atento… ahora las moscas ya saben que la rana esta allí…. Así que ahora serán más rápidas cuando salen, y algunas también pueden tardarse más en salir… así que mantente muy atento…

- Cuando el niño cometa un fallo, remarcarlo con dialogo reflexivo, por ejemplo: se te ha escapado la mosca!... por que se te escapo?... porque no la capturaste?... porque presionaste la barra antes de que saliera la mosca?...

Al final:

Guau!!!¡Muy bien! ¡Eres un campeón en estos juegos! El próximo día, también vamos a jugar a algunos juegos muy divertido.

SESIÓN 6.

Pre- números. ¿En qué consiste?

Este “juego” se utiliza para que el niño se familiarice con la representación numérica de las cantidades, ya que en los siguientes juegos tendrá que utilizar dicho conocimiento. Para eso utilizamos una plantilla en la que ayudamos al niño a entender la correspondencia entre numero y conjunto de cosas.

Entrenador: el día de hoy haremos juegos en donde tendras que decirme el número de objetos que aparecen. … puedes decirme cuantos conejos hay aquí? (señalar el grupo de conejos en la plantilla)…

Sujeto: hay cuatro…

Entrenador: muy bien!!... ahora dime cuantos hay aquí … (continua hacia abajo en la hoja, haciendo la misma pregunta… y dando reforzamiento positivo al niño)…al finalizar continuar con… muy bien!... veo que eres muy apañao con los números… vale continuemos con el siguiente juego!....

- Nota: al comenzar cada juego, recuerda mover el cursor fuera de la pantalla.

Nota: al comenzar cada juego, recuerda mover el cursor fuera de la pantalla.

Juego 14- Stroop de cuatro números.

En este juego aparecen dos conjuntos de ítems. Para comenzar cada ensayo, el niño tiene que hacer clic en la pizarra que aparece en el centro de la pantalla. Aparecen números que varían en tamaño y valor.

La tarea del niño consiste siempre en hacer clic sobre el número de mayor valor numérico (Ej. Si aparecen un “**8**”y “9”, la respuesta correcta sería el “9”, a pesar de que el “**8**”es mayor en tamaño). Si el niño acierta, aparecen tantos caramelos como indicaba el valor del número elegido.

En los primeros ensayos, aparecen dos números. Conforme avanzamos en niveles aumenta la cantidad de números que aparecen en la pizarra, y los valores de los números son más cercanos entre sí.

El juego 14 tiene 7 niveles, cada nivel tiene un color de pantalla distinto. Si el niño hace 3 ensayos incongruentes correctos pasa de nivel. Un ensayo es congruente cuando el número de mayor valor es también el de mayor tamaño. En los ensayos incongruentes el número de mayor valor no es el de mayor tamaño.

Nivel 1: aparecen 4 ensayos congruentes y 4 incongruentes, si el niño se equivoca en 1 incongruente, aparecen 3 ensayos incongruentes más, si se vuelve a equivocar aparecen otros 3…

Niveles posteriores: aparecen 2 ensayos congruentes y 4 incongruentes, si el niño se equivoca aparecen 3 ensayos incongruentes más, y así sucesivamente hasta que consiga pasar de nivel.

Procedimiento para explicar el juego.

Entrenador: Bueno, como ya te sabes los números vamos a hacer otro juego de números. Te acuerdas del juego que hicimos al principio?... vale pues este es muy parecido… lo que tienes que elegir el número que tiene más caramelos… si te enseño esta mano (con tres dedos)… y esta (con cinco dedos)… que mano crees que tiene más caramelos…

<u>Sujeto:</u> la que tienes cinco…

<u>Entrenador:</u> claro… por que cinco es más grande que tres verdad… bueno pues ahora tienes que elegir el número que tiene más caramelos…. Para poder ver el número tienes que hacer clic en la pizarra… Ese número nos dirá en donde hay más caramelos… pero sabes… tienes que tener cuidado porque a veces el que tiene más caramelos lo han dibujado más pequeñito… venga vamos a jugar…

- *Si el sujeto se equivoca, realizar el dialogo reflexivo como el siguiente ejemplo:*

<u>Entrenador:</u> ooo… te has equivocado… que paso?

<u>Sujeto</u>: no se, le di al número más grande y me dio error…

<u>Entrenador:</u> pero el número que le diste, era el más grande de tamaño?... o era el que tenia más caramelos…

<u>Sujeto:</u> el más grande de tamaño…

<u>Entrenador:</u> pero eso no quiere decir que sea el que más caramelos tiene, o si?...

<u>Sujeto:</u> no…

Entrenador: que puedes hacer para saber cuál de los dos tiene más caramelos?...

Sujeto: contar… (si no contesta, o no sabe, decir: pues puedes ayudarte contando sabes… si tienes un tres y también un 6… contando sabrás cual es el más alto…)..

Entrenador: muy bien!... porque contando sabemos qué número es más alto y que número es más pequeño verdad… vale continua..

Al final:

Guau!!!¡Muy bien! ¡Eres un campeón en estos juegos! El próximo día, también vamos a jugar a algunos juegos muy divertido.

SESIÓN 7.

Juego 13 Rana

En este juego la tarea del niño consiste en cazar moscas. Hay una rana que caza las moscas, las cuales están dentro de un bote. Para cazarlas el niño debe presionar la barra espaciadora. Se ha de indicar a los niños que han de estar muy atentos a cuando sale la mosca para que la rana pueda cazarla. En algunos ensayos la salida de la moscas está precedida por un tono. Tenemos que decirle al niño que unas veces aparecerá el tono y otras no, pero que ellos deben darle a la barra cuando la mosca salga del bote y no cuando escuchen el tono. Hay seis niveles diferentes, que manualmente habrá que cambiar al iniciar el nuevo nivel.

Nivel 1.

Catch time: 1200

Min. Wait time: 2.000 mlsg

Max. Wait time: 4.000

Nivel 3

Catch time: 900

Min. Wait time: 2.000 mlsg

Max. Wait time:6.000

Nivel 5

Catch time: 600

Min. Wait time: 2.000 mlsg

Max. Wait time: 8.000

Nivel 2

Catch time: 1.200

Min. Wait time: 2.000 mlsg

Max. Wait time:6000.

Nivel 4	*Nivel 6*
Catch time: 900	Catch time: 600
Min. Wait time: 2.000 mlsg	Min. Wait time: 2.000 mlsg
Max. Wait time: 8.000	Max. Wait time:10.000

Procedimiento para explicar el juego.

Entrenador: Te recuerdas de este juego?... ya lo habíamos jugado… cuéntame que es lo que tenemos que hacer?..

Sujeto: ayudar a que la ranita pueda comerse a las moscas…

Entrenador: bien y te acuerdas como hacíamos eso?...

Sujeto: teníamos que hacerlo con la barra espaciadora… (si en dado caso el sujeto no recuerda las instrucciones … Para eso tienes que pulsar la barra espaciadora en cuanto veas que una mosca sale del jarrón…)

Entrenador: vale pues recuerda que tienes que ser lo más rápido posible… ahora recuerdas si las moscas hacían algún ruido?.

Sujeto: debe de indicar el sonido….

Entrenador: bien!, ese es el sonido de las moscas… recuerda que tienes que prestar mucha atención para ver cuando la mosca sale… algunas harán ruido y otras no… así que tienes que estar muy atento… que tienes que hacer cuando la mosca salga?...

Sujeto: tengo que presionar la barra… (si en dado caso no se recuerda, volver a indicar las instrucciones).

Entrenador: muy bien!... entonces estás listo para comenzar….

- Si presiona la barra cuando escucha el sonido:

  Entrenador: tienes que esperar a que salga la mosca...las moscas no salen cuando suena el ruidito, así que tienes que estar atento a cuando sale la mosca.

Niveles 2 y subsiguientes

En los niveles superiores, la velocidad de las moscas aumenta, así como también el intervalo de tiempo que deben de esperar los niños para que salga la siguiente mosca es mayor. Por lo tanto se debe de indicar a los niños que deben de prestar más atención para que puedan caputrar a las moscas.

Entrenador: ahora en los siguientes niveles tienes que estar más atento… ahora las moscas ya saben que la rana esta allí…. Así que ahora serán más rápidas cuando salen, y algunas también pueden tardarse más en salir… así que mantente muy atento…

- Cuando el niño cometa un fallo, remarcarlo con dialogo reflexivo, por ejemplo: se te ha escapado la mosca!... por que se te escapo?... porque no la capturaste?... porque presionaste la barra antes de que saliera la mosca?...

Al final:

Guau!!!¡Muy bien! ¡Eres un campeón en estos juegos! El próximo día, también vamos a jugar a algunos juegos muy divertido.

Sesión 8

Juego 11- Stroop

En cada ensayo de este juego, el niño primero hace clic en el recuadro verde.

Aparecen dos conjuntos de ítems y la tarea del niño es hacer clic en el conjunto que tenga más ítems. En los primeros ensayos, el conjunto simplemente contiene frutas. En los ensayos posteriores, los conjuntos contienen dígitos numéricos; el niño tiene que seleccionar correctamente el conjunto con más ítems sin tener en cuenta el valor de los números (ej. Un conjunto de seis "2" tiene más ítems que un conjunto de tres "9" incluso cuando el digito 9 tiene un valor mayor).

El juego 11 tiene 6 niveles. Se requieren 3 ensayos correctos para avanzar al nivel siguiente. Cuando empiezan los ensayos en los que aparecen los números, sólo los ensayos incongruentes (aquellos en los que el conjunto más grande contiene los números con el valor más pequeño) cuentan como ensayos correctos.

Procedimiento para explicar el juego

Entrenador: muy bien…. Ahora vamos a hacer uno de los juegos que ya hicimos antes, te acuerdas del juego de los número y de las frutas?... en donde lo que teníamos que hacer es decir que conjunto de frutas o números es el que tiene más cantidad… Si recuerda las instrucciones, solamente recordarle las instrucciones básicas a partir de preguntas reflexivas: te acuerdas que teníamos que hacer?... que grupo de frutas marcamos?... etc…

- Si no recuerdan repetir las instrucciones:

Entrenador: tu veras aparecer en el cuadro, dos conjuntos de cosas, ya sean frutas o también números… pues lo que tienes que hacer es hacer un click en el conjunto que tenga más cantidad…. Por ejemplo: cuantos dedos tengo en esta mano (mostrar 2 dedos)… y en esta (mostrar con la otra mano 4 dedos)…..en que mano tengo la mayor cantidad de dedos???...

Sujeto: en la que tienes cuatro…

Entrenador: muy bien!... en la que tengo 4 tengo mayor cantidad de dedos…. Muy bien… pues lo mismo tienes que hacer aquí… me tienes que decir que grupo tiene la mayor cantidad… dime, que tenemos que hacer para saber que grupo tiene la mayor cantidad?...

Sujeto: tenemos que contar el número de frutas o números…

Entrenador: muy bien!... tenemos que contar el numero de frutas o números que hay en cada grupo… vale púes entonces vamos a continuar con el juego…

Niveles 2 y subsiguientes

En los niveles superiores la complejidad del juego aumenta a medida que se van mostrando grupos de objetos con número de ítems similares, grupos de ítems con números, y grupos de ítems que combinan ambos. Cuando se presentan grupos de números, es importante hacer al niño reflexionar que no es el valor del número lo que importa, sino que el número de Items que hay de ese mismo número. Así mismo, es importante hacer ver al niño que la posición de los ítems no tiene nada que ver con la cantidad de ítems presentada, recalcar que lo importante es que cuente la cantidad de ítems. Al momento que los niños cometan errores, recordar mantener un acompañamiento metacognitivo a través del diaologo reflexivo.

Cuando el niño cometa un error realizar dialogo relfexivo como el ejemplo siguiente:

- Si se confunde por la posición de ítems:

Sujeto: me di error… por que?

Entrenador: a que grupo de ítems le has dado?...

Sujeto: a este… (señalando el grupo que aparentemente tiene más… pero que por la forma de agruparlos parecen menos)..

Entrenador: y los has contado?...

Sujeto: no por que es el grupo en el que ha mas!...

Entrenador: haber estas seguro… contemos…. ves, a veces las cosas nos parecen más cuando en realidad no lo son… así que lo importante es… "Contar", no te olvides de prestar atención y contar bien…

- *Si se confunde por el valor de los números:*

Sujeto: me dio error!... pero si le di al número más grande!

Entrenador: pero contaste el número de números que había en el grupo?...

Sujeto: no porque el número era más grande!

Entrenador: bueno, pero recuerdas las instrucciones… (debe de responder: hacer click en el grupo que tenga mas ítems)… y tu diste click al grupo con el número más grande… pero no el que tenia más ítems... los habéis contado?...

Sujeto: no

Entrenador: vale pues ese fue el error…. Recuerda que tienes que contar los ítems…ponle atención al grupo de números, no al valor del número… venga, vamos a continuar, y recuerda contar bien!..

Juego 7- Retratos

Este juego está compuesto por parejas de dibujos. Los niños usan un joystick y un botón del joystick para manipular el cursor.

En cada ensayo, el niño primero hace clic en un recuadro naranja que hay en el centro de la pantalla. Esto hace que aparezca un dibujo en una de las esquinas de la pantalla. El niño hace clic en el dibujo que ha aparecido. El recuadro naranja entonces se abre y deja ver dos dibujos diferentes. El niño debe hacer clic en el dibujo que sea igual que el que hay en la esquina.

El dibujo puede diferir: en el animal que represente, en el color del fondo, en el color del borde, en la orientación de las líneas en el borde, o en características dentro del dibujo del animal.

En los primeros niveles, el dibujo difiere en múltiples aspectos, pero en niveles posteriores, los dibujos solo se diferencian en una característica. Si el niño hace clic en el dibujo correcto, las manos aplauden y el aplauso se escucha. Si el niño hace clic en un dibujo equivocado, un sonido "Oh, oh" se escucha.

El juego 7 tiene 7 niveles. Se requieren 3 ensayos consecutivos correctos para avanzar de un nivel al siguiente.

Si la velocidad del juego decrece durante el juego, por favor mira la nota sobre la velocidad de los juegos al final del punto 2.

Procedimiento para explicar el juego.

Entrenador: Bueno ahora haremos otro juego distinto…Este juego ya lo hemos hecho antes también… recuerdas el juego de los animalitos… pues volveremos a hacer el juego… recuerdas como es?... (si el sujeto contesta que si, realizar preguntas para que recuerde las reglas… y que recuerde que objetos son los que debe de prestar atención…)

- *Si no recuerda las reglas, volver a dar las instrucciones:*

Para comenzar el juego debes hacer un click en la pantalla… hazlo, veamos que pasa….

Sujeto: aparece un cuadro naranja, y un dibujo de un animal!..

Entrenador: muy bien!...ahora, mira bien la imagen del animal… dime que tiene esa imagen… pero fijate bien en todos los detalles que tiene!...

- *En este punto es importante que el sujeto se de cuenta de los detalles del dibujo, es decir… el color del recuadro, las rallas blancas, la dirección de las rallas y el fondo de la figura…. En caso de que pase por alto alguno de los detalles, realizar preguntas de manera reflexiva, para que sean capaces de detectarlos…. Dicha detección es importante para el acompañamiento metacognitivo y el dialogo reflexivo en la detección de los errores… "si el niño no sabe en qué tiene que fijarse, como sabrá que comete un error"…*

Sujeto: tiene un recuadro de color azul (o rojo)...un animalito (oso, jirafa, serpiente..)… tiene unas líneas de color blanco….

Entrenador: señalar los detalles que haya olvidado… por ejemplo: muy bien!... pero también te falto decirme algo… de que color es el fondo del dibujo? … hacia donde van las líneas blancas?...

Sujeto: haaa… es que eso no lo vi… pues tiene fondo de color (amarillo o azul)… y las líneas van hacia la (izquierda o derecha)…

Entrenador: vale, muy bien!... quiero que te recuerdes que tienes que ver muy bien todos estos detalles, porque lo que tienes que hacer es ver cuál de las dos imágenes que veras aparecer después es exactamente igual que la que aparece en la esquina… Para poder ver las otras imágenes debes de hacer click en esa imagen…. Haber hazle click para que veamos las otras imágenes…. Ahora dime, cuál de estas imágenes es exactamente igual que la que esta en la esquina….

Sujeto: esta!...

Entrenador: vale muy bien!...dime porque razón son las mismas?

Sujeto: porque los colores del recuadro son los mismos!...

Entrenador: muy bien!... ahora dime en que otros detalles te tienes que fijar?.... recuerdas que los hemos dicho hace un rato?...(debe de recordar cada uno de los detalles, si no lo hace, señalarlos en la pantalla para que los vea y los pueda detectar)…

Sujeto: el color del recuadro, el fondo del dibujo y la dirección de las líneas blancas…

Entrenador: muy bien, recuerda que tienes que ponerle mucha atención a esos detalles para que veas cual es el que es idéntico…. Venga vamos a jugar!... dale a la figura que es igual!... haz visto lo que sucede!...

Sujeto: sii… me aplauden…

Entrenador: muy bien!... pues eso es por que lo has hecho bien… el programa te dirá si lo haces bien o lo haces mal… venga vamos a jugar!...

Con frecuencia los niños ponen su dedo en el botón e inadvertidamente hacer clic cuando ellos están moviéndose hacia el target. Esto da como resultado una respuesta incorrecta. Recuérdales que no pongan el dedo en el botón hasta que ellos necesiten hacerlo.

Entrenador: Ten cuidado de no hacer clic antes de tiempo.

Niveles 2 y subsiguientes

En los primeros tres niveles, los dibujos se diferencias en varias características, lo cual hace que la detección de las diferencias sea relativamente fácil. En los niveles superiores, la dificultad aumenta debido a que las diferencias comienzan a darse en un solo aspecto, y cada vez es más sutil. En los últimos niveles, ya las diferencias se dan en la *misma figura del animalito, por lo que hay que hacer que el niño ponga atención también a las diferencias en las imágenes.*

Cuando los niños cometan un error, dar acompañamiento con dialogo reflexivo, ayudando al niño a recordar las distintas dimensiones a las que tiene que prestar atención. Por ejemplo:

- *Sujeto: y ahora por que me salió mal?...*
- *Entrenador: ha de ser por que no prestaste atención bien al dibujo… recordemos que cosas son las que debes de ver para que veas las diferencias… dímelas… (ahora es importante no señalarlas, sino que el niño las enumere verbalmente… en dado caso olvide alguna decirle: oye pero te has olvidado de una… sabes cual es?... si en dado caso el niño no la recuerda recordarlo verbalmente…)*

En el momento en que las diferencias sean en los animales propiamente dichos (últimos niveles)… darle instrucciones para que también preste atención a dichos detalles.

Sesión 9

Juego 12. La granja

En este juego, los niños tienen que meter a las ovejas dentro del corral mientras mantienen a los lobos fuera. En cada ensayo, el niño usa el joystick para hacer clic en el recuadro amarillo. El recuadro luego se mueve hacia los lados para que se vea a una oveja o a un lobo. Cuando la oveja aparece, el niño presiona el botón del joystick para poner a la oveja dentro del corral. Cuando el lobo aparece, sin embargo, el niño no debe presionar el botón (para que el lobo se quede fuera del corral). En niveles posteriores, el lobo aparece con un disfraz de oveja que hace que se parezca a una oveja.

El juego 12 tiene 6 ensayos, incluyendo un mínimo de al menos un ensayo con un lobo, se deben completar para avanzar al siguiente nivel.

Procedimiento para explicar el juego.

<u>Entrenador:</u> *Bueno ahora haremos otro juego distinto…Este juego ya lo hemos hecho antes también… recuerdas el juego de los animalitos… pues volveremos a hacer el*

juego… recuerdas como es?... (si el sujeto contesta que si, realizar preguntas para que recuerde las reglas… y que recuerde que objetos son los que debe de prestar atención…)

- *Si no recuerda las reglas, volver a dar las instrucciones:*

<u>*Entrenador*</u>*: En este juego, todas las ovejas del granjero José se han salido de su corral…. Lo que tú tienes que hacer es ayudar al granjero a poner todas las ovejas dentro del corral… pero ten cuidado, por que también hay un lobo que quiere meterse en el corral para comerse a las ovejas…. Así que asegúrate de meter solamente a las ovejas…. Los lobos se quedan afuera!...*

Bien… para comenzar a jugar lo que tienes que hacer es hacer click sobre este montón de paja, que es donde se esconden los animales…. Allí mismo veras aparecer al animal… te puede aparecer una ovejita, o un lobo… que es lo que tenemos que hacer con las ovejitas?..

<u>*Sujeto:*</u> *las tenemos que meter en el corral…*

<u>*Entrenador:*</u> *muy bien… solo las ovejas van en el corral… para meterlas en el corral, lo único que tienes que hacer click encima de la ovejita…. Así ella sabe que puede entrar en el corral…* pero ten cuidado, recuerda que hay un lobo suelto por allí… así que cuando salga no hagas click, solo espera un rato y él se ira, si haces click el lobo entrara al corral y se llevará a todas las ovejitas… así que tienes que poner atención para que no dejes entrar a ningún lobo… así que, qué tienes que hacer para que las ovejitas entren en el corral?...

<u>Sujeto:</u> tengo que hacer click en la ovejita…

<u>Entrenador:</u> muy bien… tienes que hacer click en la ovejita… y que tienes que hacer cuando aparece el lobo?....

<u>Sujeto</u>: no tengo que hacer nada para que el lobo se valla…. (si el sujeto no responde, o no sabe… repetir las instrucciones…)

<u>Entrenador:</u> muy bien!!... eso es lo que tienes que hacer… venga vamos a jugar…

Niveles 2 y subsiguientes

En los niveles superiores, la frecuencia con que aparecen los lobos aumenta. Además, puede ser que los lobos estén disfrazados de oveja, dando un poco de complejidad a la tarea. Por lo que es importante que se haga reflexión a los niños acerca de esto para que puedan regular si estrategia.

- Si el sujeto comete errores, realizar dialogo reflexivo. Por ejemplo:

<u>Sujeto:</u> me equivoque de nuevo…

Entrenador: que ha pasado?... porque te equivocaste?

Sujeto: es que le di al lobo en lugar de a la oveja…

Entrenador: y porque paso eso?

Sujeto: es que le di muy rápido…

Entrenador: muy bien… pues entonces lo que tienes que hacer para no cometer más estos errores es poner mucha atención….

- Error por lobos disfrazados de oveja:

Sujeto: hay… ese era un lobo!!... pero por que estaba de oveja?-..

Entrenador: es que ese lobo es muy listo, y tienes que tener cuidado porque ahora sabe que solo dejas entrar a ovejitas, y por eso se ha disfrazado de oveja ahora… que tienes que hacer si aparece uno de estos lobos disfrazados de oveja?...

Sujeto: no tengo que hacer click, así se va…. (si no responde, realizar un dialogo reflexivo para que se dé cuenta que no hay diferencia entre el lobo, y el lobo disfrazado de oveja)

Entrenador: muy bien!... entonces ten mucho cuidado, porque ahora te pueden aparecer lobos disfrazados de ovejas… venga a poner mucha atención… sigue!...

Juego 8. Retratos con demora

Este juego es idéntico al juego anterior, excepto que el dibujo de la esquina ahora desaparece después de que el niño haga clic en él. El niño tiene recordar el dibujo antes de hacer clic en él, y posteriormente seleccionar el dibujo que es igual en el panel.

El juego 8 tiene 7 niveles. Se requieren 3 ensayos consecutivos correctos para avanzar de un nivel al siguiente.

Si la velocidad del juego decrece durante el juego, por favor mira la nota sobre la velocidad de los juegos al final del punto 2.

Procedimiento para explicar el juego.

Entrenador: Bueno ahora haremos otro juego distinto…Este juego ya lo hemos hecho antes también… recuerdas el juego de los animalitos… pues volveremos a hacer el *juego… recuerdas como es?... (si el sujeto contesta que si, realizar preguntas para que recuerde las reglas… y que recuerde que objetos son los que debe de prestar atención…)*

- *Si no recuerda las reglas, volver a dar las instrucciones:*

Entrenador: bueno ahora haremos un juego igual al anterior… solo que con una diferencia!... haber haz lo mismo que en el anterior para que veas cual es la diferencia!...

Sujeto: ahora se desaparece la figura de la esquina…

Entrenador: eso es!... la diferencia es que ahora tienes que recordarte de la figura que has visto por que esta se desaparece!... y después tienes que decir cual de las que ves es igual a la que apareció en la esquina!...

Sujeto: pero eso será más difícil!..

Entrenador: si más difícil, pero más divertido también!... ahora tendrás que tener buena memoria!... haber si tienes buena memoria, dime que es a lo que le teníamos que prestar atención en el juego anterior?...

Sujeto: el recuadro, la dirección de las líneas, el color del fondo, y a la figura!.... (si el sujeto no lo recuerda, señalarle los elementos a los que hay que prestar atención.)

(Ayúdales hasta que puedan hacerlos por si solos).

Niveles 2 y subsiguientes

En los primeros tres niveles, los dibujos se diferencias en varias cacterísticas, lo cual hace que la detección de las diferencias sea relativamente fácil. En los niveles superiores, la dificultad aumenta debido a que las diferencias comienzan a darse en un solo aspecto, y cada vez es más sutil. En los últimos niveles, ya las diferencias se dan en la misma figura del animalito, por lo que hay que hacer que el niño ponga atención también a las diferencias en las imágenes.

Cuando los niños cometan un error, dar acompañamiento con dialogo reflexivo, ayudando al niño a recordar las distintas dimensiones a las que tiene que prestar atención. Por ejemplo:

- *Sujeto: y ahora porque me salió mal?...*
- *Entrenador: ha de ser porque no prestaste atención bien al dibujo… recordemos que cosas son las que debes de ver para que veas las diferencias… dímelas… (ahora es importante no señalarlas, sino que el niño las enumere verbalmente… en dado caso olvide alguna decirle: oye pero te has olvidado de una… sabes cuál es?... si en dado caso el niño no la recuerda recordarlo verbalmente…)*

En el momento en que las diferencias sean en los animales propiamente dichos (últimos niveles)… darle instrucciones para que también preste atención a dichos detalles.

Sesión 10

Juego 14- Stroop de cuatro números.

En este juego aparecen dos conjuntos de ítems. Para comenzar cada ensayo, el niño tiene que hacer clic en la pizarra que aparece en el centro de la pantalla. Aparecen números que varían en tamaño y valor.

La tarea del niño consiste siempre en hacer clic sobre el número de mayor valor numérico (Ej. Si aparecen un "**8**"y "9", la respuesta correcta sería el "9", a pesar de que el "**8**"es mayor en tamaño). Si el niño acierta, aparecen tantos caramelos como indicaba el valor del número elegido.

En los primeros ensayos, aparecen dos números. Conforme avanzamos en niveles aumenta la cantidad de números que aparecen en la pizarra, y los valores de los números son más cercanos entre sí.

El juego 14 tiene 7 niveles, cada nivel tiene un color de pantalla distinto. Si el niño hace 3 ensayos incongruentes correctos pasa de nivel. Un ensayo es congruente cuando el número de mayor valor es también el de mayor tamaño. En los ensayos incongruentes el número de mayor valor no es el de mayor tamaño.

Nivel 1: aparecen 4 ensayos congruentes y 4 incongruentes, si el niño se equivoca en 1 incongruente, aparecen 3 ensayos incongruentes más, si se vuelve a equivocar aparecen otros 3…

Niveles posteriores: aparecen 2 ensayos congruentes y 4 incongruentes, si el niño se equivoca aparecen 3 ensayos incongruentes más, y así sucesivamente hasta que consiga pasar de nivel.

Procedimiento para explicar el juego.

Entrenador: *Bueno ahora haremos otro juego distinto…Este juego ya lo hemos hecho antes también… recuerdas el juego de los animalitos… pues volveremos a hacer el juego… recuerdas como es?... (si el sujeto contesta que si, realizar preguntas para que recuerde las reglas… y que recuerde que objetos son los que debe de prestar atención…)*

- *Si no recuerda las reglas, volver a dar las instrucciones:*

<u>Entrenador:</u> Bueno, como ya te sabes los números vamos a hacer otro juego de números. Te acuerdas del juego que hicimos al principio?... vale pues este es muy parecido… lo que tienes que elegir el número que tiene más caramelos… si te enseño esta mano (con tres dedos)… y esta (con cinco dedos)… que mano crees que tiene más caramelos…

<u>Sujeto:</u> la que tienes cinco…

<u>Entrenador:</u> claro… por que cinco es más grande que tres verdad… bueno pues ahora tienes que elegir el número que tiene más caramelos…. Para poder ver el número tienes que hacer clic en la pizarra… Ese número nos dirá en donde hay más caramelos… pero sabes… tienes que tener cuidado porque a veces el que tiene más caramelos lo han dibujado más pequeñito… venga vamos a jugar…

- *Si el sujeto se equivoca, realizar el dialogo reflexivo como el siguiente ejemplo:*

<u>Entrenador:</u> ooo… te has equivocado… que paso?

<u>Sujeto</u>: no se, le di al número más grande y me dio error…

<u>Entrenador:</u> pero el número que le diste, era el más grande de tamaño?... o era el que tenia más caramelos…

<u>Sujeto:</u> el más grande de tamaño…

<u>Entrenador:</u> pero eso no quiere decir que sea el que más caramelos tiene, o si?...

<u>Sujeto:</u> no…

<u>Entrenador:</u> que puedes hacer para saber cuál de los dos tiene más caramelos?...

<u>Sujeto:</u> contar… (si no contesta, o no sabe, decir: pues puedes ayudarte contando sabes… si tienes un tres y también un 6… contando sabrás cual es el más alto…)..

<u>Entrenador</u>: muy bien!... porque contando sabemos qué número es más alto y que número es más pequeño verdad… vale continua..

Al final:

Guau!!!¡Muy bien! ¡Eres un campeón en estos juegos! El próximo día, también vamos a jugar a algunos juegos muy divertido