The relation between Executive Functions and Emotion Regulation in Preschool Children

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Executive Functions (EF) and Emotion Regulation (ER) are essential for children’s ability to regulate and control thoughts, behavior and emotions but the developmental relations between them are unclear. The present study was performed within the project PsPATHS with the purpose to investigate the relation between EF and ER. Performance on cognitive tasks tapping inhibitory control, working memory and cognitive flexibility were combined with teacher report of ER in 55 four to five year old preschool children. Contrary to the hypothesis, no significant relations could be established between EF and ER in this sample. For the EF components, the result showed a significant association between inhibitory control and cognitive flexibility, however, no further associations could be evidenced. The study demonstrates an advantage in using multiple measures and suggests that attention along with motivational and affective aspects of EF should be considered in future research of children’s ability to regulate emotions.

Imagine a four to five year old child at pre-school. Play-time is over, lunch is heading up and the teacher tells the children to tidy up the room together. Now the child has to stop the on-going play and instead focus on sorting, remembering which toy should go into which box and then put them in to the appropriate place. The big dinosaur gets stuck crossways and the child becomes frustrated, again and again trying to get the box onto the shelf. Putting down the box in anger, the child resists the impulse to throw away the stupid T-Rex and suddenly notices that the toy can be put into the box in another way. After another try, the box gets in place and the child can pleased join the other children for lunch.

This scenario visualizes a typical situation in preschool where a child uses Executive Functions (EF) to regulate thoughts and behavior and Emotion Regulation (ER) to regulate elicited emotions. The top-down cognitive processes included in EF’s are essential for planning, problem-solving and for a successful goal-directed behavior but also for deliberate self-regulation of emotions (Carlson & Wang, 2007; Diamond, 2013). Research has found that sound EF as well as well-developed self-regulation of emotions promotes positive peer relations and social interaction with group members. EF’s are also related to school-readiness, academic success and later well-being (e.g. Bierman, Nix, Greenberg, Blair & Domitrovich, 2008; Denham, 2006). On the other hand, deficits in these abilities can lead to an increased risk for negative long-term outcome, adjustment problems in school and in social life but also a risky behavior, e.g. making risky choices or using harmful substances (Hughes & Ensor, 2008).
There is a substantial development in children's EF and ER during the preschool-years, but little is known about the developmental relations between EF and ER (Carlson & Wang, 2007; Liebermann, Giesbrecht & Müller, 2007). Limited research has examined this relation and, traditionally, from different point of views, e.g. social-emotional behavior (Rhoades, Greenberg & Domitrovich, 2009; Ursache, Blair, Stifter & Voegtline, 2013) or cognitive-neuropsychological abilities (Carlson & Wang, 2007; Zelazo & Cunningham, 2007). Hence, there is still much left to understand about the possible interrelations, how EF contribute to ER in preschool children. The purpose of the present study is to further examine the relation between different aspects of EF and ER in preschool children. Therefore, in the following sections different aspects of EF and of the concept ER will be introduced followed by arguments about the relation between EF and ER.

Executive Functions - development and assessment

The umbrella term Executive Functions (EF) is considered to comprise the cognitive processes needed to intentionally regulate ones thoughts and actions and to maintain goal-directed behavior. This requires the ability to keep focus, to manage unexpected changes in the situation and to be able to leave out irrelevant information (Best & Miller, 2010; Brocki, 2007; Diamond, 2013; Miyake & Friedman, 2012). There is general agreement that EF's are built up by tree core components; inhibition, working memory and cognitive flexibility (Best & Miller, 2010; Diamond, 2013; Miyake et al., 2000; Miyake & Friedman, 2012). Research by Miyake and colleagues has found that, in adults, the separate core components may share underlying cognitive processes, often referred to as unity and diversity of EF (Miyake et al., 2000; Miyake & Friedman, 2012).

Development of EF is protracted and the core components seem to evolve sequentially, yet overlapping, beginning early in life with rudimentary forms of inhibition. The preschool years is suggested to be a period where the different EF components begin to interact (Best & Miller 2010; Diamond, 2013; Garon, Bryson & Smith 2008). Furthermore, this coordination of EF components seems to have its own trajectory (Diamond, 2013; Garon et al., 2008).

In psychological science terms from different perspectives often overlap with EF. The terms executive control or cognitive control are sometimes used more or less synonymously with EF’s, emphasizing the top-down control aspect of managing thoughts and behavior (Brocki, 2007; Zelazo & Carlson, 2012). Temperament-personality models often use the related term effortful control for top-down control of attentional and behavioral inhibition (Johansson, 2015; Rhoades et al. 2009; Rueda, Posner & Rothbart, 2005). In this thesis, the EF terminology unfolded by Diamond (2013) are used, as these terms focuses on the mental processes, regardless if considered as part of a personal trait or as a cognitive skill.

Assessment of EF is difficult in that they are considered to be separate functions, yet to also share underlying processes. EF assessment in young children is even harder because the different EF components may not be as well differentiated as in adults, i.e. the pattern of correlations between EF components may differ at different ages (Best & Miller, 2010, Brocki, 2007). Another complication is that many EF tasks, originally
evolved to assess executive dysfunction in adults, have been simplified to fit children, with the risk that the intended EF measure no longer is valid (Brocki, 2007; Carlson, 2005; Garon et al., 2008). Lack of suitable measurements have earlier limited the work (Blair, Zelazo & Greenberg, 2005) but recent creation and systematization of age-appropriate EF tasks have resulted in improved assessment of specific aspects of EF in preschool children (Blair et al., 2005; Carlson, 2005; Garon et al., 2008).

Inhibitory control
In this thesis, inhibitory control is defined broadly (Diamond, 2013), comprising interference control and response inhibition. Interference control includes suppressing pre-potent mental representations, like unwanted thoughts or memories, but also paying attention to a certain stimulus and ignoring distracting ones irrelevant to the task at hand (Diamond, 2013). Interference control can be utilized for distraction within a task as well as from distraction outside a task (Barkley, 1997). Response inhibition involves control over behavior, in order to override an impulse and instead do what’s more appropriate or needed (Diamond, 2013).

Inhibition is considered the first EF component to develop (Miyake et al., 2000). Between ages 3 and 6 children's performance on EF tasks increases (Carlson, 2005), specifically on different types of inhibitory control tasks (Best & Miller, 2010; Carlson & Wang, 2007; Garon et al., 2008). To inhibit a dominant response like resisting to eat a treat (simple inhibition) can successfully be performed by age 4. More difficult is to hold a task rule in mind or to inhibit a response and produce an alternative response (complex inhibition), which rapidly improves in 3 to 4 year old children (Best & Miller, 2010; Garon et al., 2008). This requires remembering what to inhibit and, thus, working memory and inhibitory control supports one another, and one is rarely needed without the other (Diamond, 2013).

Working Memory
The concept working memory (WM) includes the ability to maintain and manipulate information over a brief period of time without support from external cues (Best & Miller, 2010; Diamond, 2013; Miyake et al., 2000). The developmental course of WM seems to be related to the executive demands on the task, with less demanding tasks being mastered earlier in development (Best & Miller, 2010; Garon et al., 2008). Complex WM tasks (maintenance and manipulation of information) seems to have a prolonged development whereas simple WM tasks (hold information in mind over a delay) successfully can be performed by preschool children (Diamond, 2013; Garon et al., 2008). In preschool children WM is commonly assessed with tasks that require both maintenance and manipulation of information (Best & Miller, 2010; Garon et al., 2008) but for young children this may to large extent be beyond their ability (Diamond, 2013) and a forward span task can be more appropriate (Carlson, 2005; Garon et al., 2008). However, by some, holding information over a delay is more considered a measurement of short term memory, STM (Diamond, 2013; Tillman, Nyberg & Bohlin, 2008).

Furthermore, the age of WM mastery seems more to be dependent on the degree of processing than on the content to be processed. Children tend to perform better on spatial than verbal WM tasks but, still, the developmental trajectories seem to be
similar, with improved performance on both verbal and visuo-spatial WM tasks from the preschool years (Best & Miller, 2010; Garon et al., 2008).

Working memory is essential for activities where one needs to hold in mind what happened earlier and relate it to what comes later. This is critical for being able to change perspectives or to adjust to changed demands or priorities (Diamond, 2013), i.e. to be flexible.

**Cognitive Flexibility**

The third core EF component, cognitive flexibility, is considered to comprehend the ability to see things from many perspectives, to adjust to changed demands and to change how we think about something, for example in order to find a new way to solve a problem (Diamond, 2013). Just like when the preschool child in the first paragraph sees another way to fit the toy into the box so the box can fit onto the shelf. Cognitive flexibility also includes shifting or switching between mental states, rule sets or tasks (Miyake et al., 2000). All these abilities require and build on both inhibitory control and WM processes and thus emerge later in development (Best & Miller, 2010; Diamond, 2013).

A preschool child can easily sort items by one dimension, for instance to sort pictures either by color or by shape (Best & Miller, 2010; Carlson, 2005; Diamond, 2013). When the child then is instructed to shift the sorting rule, e.g. from color to shape, a new stimulus-response relation must be activated and the previous rule has to be suppressed. This can be managed at an age of four years, while younger children tend to continue to sort by the first rule, despite being able to describe the new rule (Best & Miller, 2010; Diamond, 2013). However, to continuously switch between two different dimensions or tasks are far more difficult and develops through adolescence (Brocki & Tillman, 2014; Davidson, Amso, Anderson & Diamond, 2006).

Cognitive flexibility can be demonstrated in the Dots task, later named Hearts and Flowers (Davidson et al., 2006). The task includes three trials, presented in the order congruent, incongruent and mixed trial. The response site is either presented at the same side as a striped dot (congruent) or opposite a solid dot (incongruent), see Figure 1. In the congruent trial WM requirements are low. In the incongruent trial WM load is increased and inhibitory control is required, as a new rule is valid and the dominant response to respond on the same side as the visual stimulus has to be inhibited. In a study with 325 subjects, 4 to 45 years age, results showed that reaction time (RT) is longer and accuracy is decreased in incongruent trials compared to congruent trials, although not significantly for the youngest children (Davidson et al., 2006).

Switching back and forth, continuously re-mapping the stimulus-response association, place great demands on maintenance and update of a mind set and on inhibitory control (Best & Miller, 2010; Davidson et al., 2006; Diamond, 2013). When congruent and incongruent trials are inter-switched (mixed trial) the child has to successfully recall both rules based on the location of stimulus and respond accordingly (Davidson et al., 2006). As Diamond (2013) put it "...it is easier to inhibit a dominant response all the time than only some of the time." (p. 151).
Moreover, performance on a non-switch trial (consecutive trials with the same rule) is faster and more accurate than a switch trial (shift to new rule) (Davidson et al., 2006). Thus, the difference between a switch trial and a non-switch trial within a mixed trial block lead to a cost in speed and accuracy, Local Switch Cost (LSC), see Figure 1. Thus, what trials came before a particular trial matters but it also matters what kind of block a given trial occurs in. Performance on a non-switch trial is slower and less accurate when presented within a mixed block than in a single-task block (Congruent or Incongruent). This difference in speed and accuracy is called Global Switch Cost (GSC) (Davidson et al., 2006).

For preschool children the effect of context, i.e. GSC, has been shown to be greater on congruent trials than on incongruent trials (Davidson et al., 2006), as young subjects are slower and less accurate on incongruent trials (floor effects). Also, percentage of correct responses (accuracy) seems to be a more sensitive measure than RT for younger children (Davidson et al., 2006). In a study by Brocki and Tillman (2014) with children age 5 to 14 years ($N=117$), GSC were found to be more related to cognitive flexibility than was LSC. Therefore, cognitive flexibility in preschool children can be expected to be most salient in GSC for Congruent trials.

Figure 1. Cognitive Flexibility Task. GSC=Global Switch Cost, LSC=Local Switch Cost, N-S=Non-switch trial, S=Switch trial. Adjusted from Davidson and colleagues (2006).
The Relation between EF Components

Previous studies of EF support the idea to use Miyake's (Miyake et al., 2000) unity-diversity framework as a starting point to examine EF development (Brocki, 2007, Best & Miller, 2010, Diamond, 2013; Garon et al., 2008).

Miyake and colleagues (Miyake et al., 2000; Miyake & Friedman, 2012) and Diamond (2006, 2013) have used confirmatory factor analysis (CFA) in studies that supports a three-factor model. As discussed by Garon and colleagues (2008), Diamond’s model (2006) consider WM, inhibition and cognitive flexibility as dissociable processes that show separate developmental paths and include attention as an important factor for all three components. In contrast, Miyake and colleague’s model (2000) includes separable but moderately correlated components with a common underlying mechanism, most likely inhibition (Miyake & Friedman, 2012). Research has so far not established if these relations also can be seen in early childhood. It may be that in preschool children, the EF components may not be as well differentiated as in older children and adults. However, both studies presented above shows that the separate EF components seems to develop at different paces at different ages, in other words, that the degree of unity and diversity may change developmentally.

There seems to be substantial need for inhibition and WM processes for shifting, in that inhibition is required to be able stop the present mental set and WM is required to recall the mental set to shift to (Best & Miller, 2010). The role of WM and inhibition in set shifting has been examined in school-aged children by Brocki and Tillman (2014), where inhibition was suggested to be the initiation of the process to slow down the initial response associated with the previous rule and instead activate the current rule maintained in WM. Moreover, despite a substantial correlation between the two EF components, it was the specific variance of WM and inhibitory control respectively that was important for cognitive flexibility. This emphasizes the importance of further studies to examine if this distinction between common and independent variance of EF components can be seen in preschool children.

WM supports inhibition in that one must hold the task’s goal in mind to know what to inhibit. Inhibition can also help WM, by sorting out irrelevant information and suppress thoughts not relevant for the goal held in mind (Best & Miller, 2010; Diamond, 2013). Good inhibition seems to allow a delay and make it possible for WM and cognitive flexibility to be activated (Barkley, 1997; Diamond, 2013), which is considered essential for many everyday tasks (Diamond, 2013). However, the question about how EF in preschool children relate to each other remains to be further explored.

From the situation described in the beginning, it is clear that several EF components most likely would be involved in supporting the child towards the goal, but it is not clear to what extent these components are related to each other. EF and perhaps inhibition in particular, seems to be the foundation for self-control (Diamond, 2013; Johansson, 2015; Miyake & Friedman, 2012), e.g. resisting temptations and to act impulsively, and to self-regulate elicited emotions (Carlson & Wang, 2007; Liebermann et al., 2007). Another aspect, which may be of importance to task performance, is associated with the intensity of the elicited emotion and also the child’s motivation to
master the task in an upset situation (Carlson, 2005; Zelazo & Carlson, 2012; Zelazo & Cunningham, 2007).

Emotion Regulation - development and assessment
Widely understood, Emotion Regulation (ER) is seen as successful management of emotional arousal, in order to keep focus on an ongoing activity or a goal (Liebermann et al., 2007; Zelazo & Cunningham, 2007) or to facilitate social and emotional interaction with the environment (Bierman, et al., 2008, Rydell, Berlin & Bohlin, 2003). Regulation of emotions includes physiological, cognitive and behavioral processes which can be affected through various strategies, with and without the assistance of others (Carlson & Wang, 2007; Rydell et al., 2003; Zelazo & Cunningham, 2007). ER is one of the pillars of the overarching term Emotional Competence, which further includes empathy and emotional awareness regarding self and others (Bierman et al., 2008). Although there are a number of closely related concepts, such as executive attention and effortful control (Johansson, 2015; Rueda et al., 2005), stemming from different research traditions, e.g. temperament, the definition of ER used in this thesis involves the regulation of emotions through conscious, top-down regulatory processes.

Consciously regulating actions and emotions involves on-line monitoring and modulation of one’s emotion expression (Carlson & Wang, 2007; Zelazo & Cunningham, 2007), and is often done in order to fulfill another personally relevant future goal. ER includes down-regulating intense emotions as well as up-regulating mild emotions, when imposed by the situation (Carlson & Wang, 2007; Rydell et al., 2003). In research, the focus has mostly been on negative emotions, like anger and sadness, whereas regulation of positive emotions and exuberance (i.e. overwhelming joy) has seldom been addressed (Cole, 2014; Rydell et al., 2003). In fact, difficulties in regulation of intense emotions, both positive and negative, stands out as important aspects of maladaptive behavior in children (Rydell et al., 2003) which in turn has been linked to low inhibitory control (Rhoades et al., 2009; Rydell et al., 2003).

Historical, ER in preschool children has often been assessed by rating scales to parents and preschool teachers, with the aim to tap children’s behavior in everyday situations (Diamond, 2013; Rydell et al., 2003). Additionally, observational measures, such as a structured disappointment procedure where children have to suppress their emotional expression, have been used to assess ER skills (Carlson & Wang, 2007; Lieberman et al., 2007).

As with EF, there is a substantial development of ER during the pre-school years (Carlson & Wang, 2007; Zelazo & Cunningham, 2007). However, developmental research of ER has so far to a large extent been performed from a temperamental point of view, then often termed self-regulation, where aspects like emotionality, emotion understanding and social context has been included (Camras & Shuster, 2013; Rydell et al., 2003). Very little research has focused on the cognitive, EF related, aspects of ER, or a combination of the two. Sokol & Müller (2007) argues that although there is broad agreement about the developmental course and the content of children’s self-regulation, research is still divided when it comes to the role of cognition and emotions for the development of children’s self-regulation. Furthermore, other researchers state that when emotions are regulated through deliberate and conscious cognitive processing, this
is said to be founded on executive functioning (Zelazo & Cunningham, 2007) and that as emotion and cognition are intricately linked, bidirectional influences between EF and ER are likely (Carlson & Wang, 2007).

**Relation between Executive Functions and Emotion Regulation**

Both EF and ER strengthens significantly during the pre-school years, continuing to improve throughout childhood, adolescence and into adulthood (Carlson & Wang, 2007; Zelazo & Cunningham, 2007). However, limited research has investigated the relation between EF and ER (Sokol & Müller, 2007). Developmental research based on, for instance, Miyake and colleges (2000) framework has found that inhibition seems to be strongly associated with ER, but also that EF components seems to have different trajectories and thus may relate differently to ER at different ages.

A study of sixty 3-, 4- and 5-year old children by Liebermann and colleagues (2007) showed that parental ratings of EF was not related to the children’s performance on a ER task. Opposed to the author’s assumption that inhibition is involved in ER, no significant correlations were found between the children’s performance on EF tasks, (inhibition, WM and shifting included) and parental rating of their children’s EF and ER in everyday situations. However, as measured by parent ratings, shifting explained a unique amount of variance in children’s ability to control their emotions in everyday situations. The authors discussed that multi-method measures of EF and ER may tap into different aspects of both constructs and that parent ratings of everyday behaviors may correspond to more general processes of EF than measures of specific EF processes. Liebermann and colleagues (2007) further discuss that this can account for the lack of within-construct correlation between performance-based and parental measures. It was concluded that the unique contribution of each aspect of EF to ER remains unclear.

Carlson and Wang (2007) examined the relation between inhibitory control and ER in 4 to 6 year old children (N=53) in an observational study. Their study comprised behavior measures of inhibitory control and ER along with parental reports of ER and self-control. Results showed that individual differences in inhibitory control were significantly correlated with children’s ability to regulate both negative and positive emotions, and remained so after controlling for age and verbal ability. Also, parent report of self-control was significantly correlated with children's performance on inhibitory control. The authors presented three possible interpretations of the overall results. First, inhibitory processes underlie and are necessary for ER in that inhibitory control enable the suppression of unwanted emotions. Also, the link between inhibitory control and ER was suggested to lie in the same underlying requirements; preventing an impulsive response and carrying out the opposite act. Second, ER plays an essential role in inhibitory control as good ER frees up resources for the suppression of thoughts and actions that interfere with the task or goal at hand. Third, a bidirectional relation between EF and ER was discussed where deliberate self-regulation of emotions is performed via conscious cognitive processing. Such an integrative model has been proposed by Zelazo and Cunningham (2007) where both control processes for affective/motivational representations (hot EF) and higher-order control processes for abstract information (cool EF) is hypothesized to be involved in ER. This interrelation of EF and ER is also supported by neurocognitive findings that EF and ER are likely to
draw on common neural substrates (Carlson & Wang, 2007) and that affective and non-affective information seems to activate slightly different frontal and prefrontal neural networks (Zelazo & Cunningham, 2007). Therefore, different neural networks can be activated not only depending on the degree of involvement of EF and ER control processes but also based on the motivational or affective significance of the task.

The information presented in this section reflects the complexity in the relation between EF and ER and emphasizes the importance of further understanding. Research has shown associations between EF and ER that further needs to be proven (Best & Miller, 2010; Diamond, 2013). Especially, the contribution of specific EF components for ER in preschool children should be explored, by including various measures for inhibitory control, working memory and cognitive flexibility (Carlson & Wang, 2007; Liebermann et al. 2007). Indeed, Carlson & Wang (2007) point out that many earlier studies have used temperament scales (applicable to other, ER related concepts) and/or a limited number of EF measurements, and indicate that further studies should be made where different aspects of inhibition are included.

Aim
The aim of the present study is to examine the relation between different aspects of EF and ER in four to five year old preschool children. This is achieved by using results from cognitive tasks, encompassing the three EF components, and items from a teacher questionnaire targeting regulation of positive and negative emotions.

The research questions are:
1. How do the measurements for the specific EF components relate to each other and to teacher reports of children’s ER?

   The hypothesis is that, in this sample, there should be significant associations between measurements of inhibitory control, working memory and cognitive flexibility. Moreover, significant associations should be found between measurements of EF, specially inhibitory control, and ER.

2. Do all three EF components share variance with ER or does a specific EF measurement give unique contribution to ER?

   This is considered an open question as the relation between EF and ER in preschool children has not been adequately explored in previous research.
Method

Preschool PATHS (Promoting Alternative Thinking Strategies) is a universal, teacher-taught curriculum designed to improve preschool children’s emotional and social competences (Domitrovich, Cortes & Greenberg, 2007). The core is the emotional component, that aims to emphasize the child’s affective awareness in oneself as well as in others and to support children’s own ability to self-regulate. At the Department of Psychology, Stockholm University a research program is conducted during 2012-2016, with the aim to adapt the curriculum to Swedish conditions and to evaluate the outcome in Swedish preschools. As this project includes mapping of children’s cognitive and executive abilities as well as their social and emotional competences, it provides an excellent opportunity to study the relation between EF and emotional regulation in preschool children.

Design and Recruitment

The present study was performed as a cross-sectional study within the project PsPATHS at the Department of Psychology, Stockholm University. Ethical permission for the PsPATHS project was granted 2012-11-08; registration number: 2012/1741-31/5. Preschools (municipal and private) were recruited by researchers within the PsPATHS project and information were given in written and verbal form. After accepted participation, children 4 to 5 years old at the preschool were recruited. Written and verbal information were given to the parents from the preschool teachers and in some cases by the researches. When appropriate, information were given in languages spoken by the parents. Children participated only when parents had given informed, written consent.

Participants

Participants were 56 four to five year old typically developing children, mean age 60,6 months (SD=6,5). The children were recruited from preschools in three communities in the Stockholm area. In this sample, native language was other than Swedish for 14,5 % of the children, compared to a national average of 22 % in 4 and 5 year old children (Skolverket, 2013). At date for testing the age span in the sample were from 3 years 11 months to 5 years 11 months. Apart from age, no specific exclusion criteria was set up. One child, for whom the majority of the tasks were unfinished, was excluded from the study (N=55). Demographical data for participating children are presented in Table 1.

Materiel for assessment of Executive Functions

EF was assessed by four tasks designed to tap simple and complex inhibitory control, one task for assessment of verbal working memory and one task for cognitive flexibility (see Table 2). Each task is further described below. For the computer based tests a computer tablet with internet connection was used.

Table 1. Demographical Data for Participating Children

<table>
<thead>
<tr>
<th>Data type</th>
<th>Botkyrka</th>
<th>Danderyd</th>
<th>Järfälla</th>
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<tbody>
<tr>
<td>Number of children (N)</td>
<td>13</td>
<td>31</td>
<td>11</td>
</tr>
<tr>
<td>Gender F/M (n)</td>
<td>7/6</td>
<td>17/14</td>
<td>5/6</td>
</tr>
<tr>
<td>Age in months (SD)</td>
<td>64,5 (3,8)</td>
<td>61,8 (5,8)</td>
<td>52,4 (3,2)</td>
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Table 2. Overview of Executive Function Tasks and ER Task

<table>
<thead>
<tr>
<th>Task</th>
<th>EF Component/ ER</th>
<th>Design</th>
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<tbody>
<tr>
<td>Statue</td>
<td>Inhibition (EF)</td>
<td></td>
</tr>
<tr>
<td></td>
<td>motor response suppression,</td>
<td>Motoric</td>
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<tr>
<td></td>
<td>distraction outside task</td>
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<tr>
<td>Go/No-go</td>
<td>pre-potent response</td>
<td>Computer based</td>
</tr>
<tr>
<td>Knock and Tap</td>
<td>interference control of motor response, within-task interference</td>
<td>Motoric</td>
</tr>
<tr>
<td>Stroop</td>
<td>interference control of verbal response, within-task interference</td>
<td>Computer based</td>
</tr>
<tr>
<td>Word span</td>
<td>Verbal WM</td>
<td>Verbal</td>
</tr>
<tr>
<td>Apples &amp; Pears</td>
<td>switching between two mind-sets</td>
<td>Computer based</td>
</tr>
<tr>
<td>The Emotion Questionnaire</td>
<td>anger, fear, sadness, exuberance</td>
<td>Teacher report</td>
</tr>
</tbody>
</table>

*Inhibition*

Four tasks, described below, were used to tap different aspects of inhibition. Besides the distinction between interference within a task and interference from a distraction outside a task, the four tasks also requires different degree of WM. Statue is considered to tap simple response inhibition, whereas complex inhibition is assessed with the other inhibition tasks, see Table 2.

The task Statue is a sub test of the neurocognitive test battery NEPSY (NEPSY; Korkman, Kirk & Kemp, 1998, 2000). It requires a minimal load on working memory and is designed to assess behavioral control and ability to inhibit impulsive reactions. The child was instructed to stand still in silence with eyes closed for 75 sec, without responding to noise distractions from the experimenter, such as knocking on table and coughing. The score was the total number of correct responses, given two points for each 5-second intervals with no movements or sounds, maximum 30 points. Reliability for Statue is not available for Swedish children, see Korkman et al. (1998, 2000) for test-retest based on American children.

In the computer based task Go/No-Go (Berlin & Bohlin, 2002, Brocki, Nyberg, Thorell & Bohlin, 2007) the child’s ability to inhibit a pre-potent motor response is assessed in two conditions and with four stimuli; a red square, a blue square, a red triangle and a blue triangle. In the first condition, the child was instructed to press a key ("go") on a computer tablet only when blue figures (frequent stimuli) appears on the screen and to make no response ("no-go") when a red figure (infrequent stimulus) appears. In the
second condition, the instruction was to press a key only when a square appears (frequent stimulus) and not to press when a triangle appears on the screen. The task included in total 60 stimuli with a "go-rate" of 68.3%. Thus, the prepotency within the task consists of the "go-targets". Each stimulus was presented for 800 ms, followed by a response time of 1700 ms and a waiting time of 1700 ms before the next stimulus. Score was commission error (pressing a key when a "no-go" stimulus was presented), as low scores of commission errors corresponds to good inhibition.

*Knock and Tap* is a sub test of the neurocognitive test battery NEPSY (NEPSY; Korkman, Kirk & Kemp, 1998, 2000), tapping within-task interference control of a motor response. The task was performed in two blocks, in series of knocks with knuckles or fist and taps with palm. In the first block the child was instructed to perform the opposite action as the experimenter, knocking with knuckles when experimenter is tapping with palm and vice versa. In the second, more difficult block, the child was instructed to knock with knuckles when experimenter knocks with fist and vice versa, and to not respond at all when experimenter taps with palm. The score was the total number of correct responses for both blocks, maximum 30 points. Split-half reliability for the Knock and Tap task is 0.88 (Korkman et al., 1998, 2000).

The *Stroop* task is an adapted version (Berlin & Bohlin, 2002) of the Stroop-like Day-Night task (Gerstadt, Hong & Diamond, 1994) and is designed to tap within-task interference control of a verbal response. This inhibition task requires the highest WM load and for young children visual cues can help to reduce WM load and improve inhibition performance (Diamond, 2013). In this Stroop task the child was presented with two pair of pictures on a computer tablet, each consisting of pictures showing the opposite of each other, i.e. large-small and up-down. The task was performed in two blocks with 24 presentations each, and the child was instructed to say the opposite word as quick as possible. In block 1 the first twelve pictures showed either up or down and the following twelve pictures either large or small. In block 2 the four pictures were presented in a mixed order. Total stimulus interval was 4000 ms - 4500 ms, including a presentation time of 1500 ms (1000 ms in block 2) and a waiting period before the next stimulus was presented. Registrations were made for correct answer (the opposite), wrong answer (the picture) and number of corrections (naming or starting to naming the picture and then correcting oneself). In the present study scores were correct answers, maximum 48 points. The same version of this task has been used by Thorell & Wählstedt (2006), who reported adequate test-retest reliability ($r = .84$, $p < .0001$) for 22 children 4 to 5 years old, tested two weeks apart.

**Working Memory**

To assess verbal working memory, a word span task (Tillman et al., 2008) based on the Digit Span subtest of the standardized WISC III test battery (Wechsler, 1994/1992) was used. Series of two to six words were read to the child by the experimenter, each series containing two trials with different words. The child was instructed to remember and after each trial verbally repeat the words in the same order in which they were presented. Words were one- or two-syllable words familiar to 4 to 5 year old children. Performance was scored as total number of correct word-pairs, maximum 30 points. For example, for the three-word series "Rabbit-Roof-Stick" the word-pairs "Rabbit-Roof" and "Roof-Stick" renders one point each while the pair "Rabbit-Stick" gives zero points.
Cognitive flexibility
This ability was assessed with the computer based task Apples & Pears equivalent to the Dots test, later named Hearts and Flowers, designed by Davidson and colleagues (2006). The task consists of three conditions with 20 trials each, performed in three blocks. Prior to each block, the child was shown pictures of what would appear on the computer tablet screen. In the first block, Apples, the child was instructed to press a key at the same side as the stimuli when an apple appears on the screen (congruent trial). The child had a short practice and then one trial of the first block. The second block, Pears, comprise to press a key at the opposite side of the stimuli when a pear is visible on the screen (incongruent trial). In the third condition, Apples & Pears (mixed trial), the congruent and incongruent trial was inter-switched (according to a random set up) and the child has to switch between the two mind-sets and respond accordingly. Presentation time of stimulus was 2500 ms followed by a inter-stimulus interval of 500 ms, where a fixation cross is shown. Before the start of each block the experimenter reminded the child of the current rule, e.g. "Remember, apple means same side, pear means the opposite side.", in order to decrease WM load. Response time (RT) and % correct answers were registered for each block and for the congruent and incongruent trials within the mixed block. A trial was considered correct if (a) the first response after a stimulus was correct and (b) RT was >200 ms. In the present study Global Switch Cost for Congruent and Incongruent trials were used as score for cognitive flexibility.

Material for assessment of Emotion Regulation
To capture the children's ability to regulate their emotions, a teacher report, The Emotion Questionnaire (Ry dell et al., 2003) was used. The questionnaire is designed to assess emotionality and ER in 5- to 8-year-old children, containing nine items for negative and positive emotions separately. From these, four items were included in the present study. Two items were used for ER of negative emotions (anger/fear/sadness); "It is easy for others to calm him/her down or get in a better mood" and "He/she has difficulties calming down on his/her own". In addition, two items regarding ER of positive emotions (exuberance) were included; "It is easy for others to make him/her quiet down" and "He/she has difficulties quieting down on his/her own". Negative emotions were merged into the same item, rather than treated like separate items. A Lickert-type five-step response scale were used for each item, with scale endpoints 1 = doesn't apply at all, and 5 = applies very well to this child. Items were reversed-scored as needed and averaged into three measures: regulation of respectively positive emotions, negative emotions and positive and negative emotions averaged (ER Global). High scores correspond to good ER. Rydell and colleagues (2003) established a test-retest reliability for the emotion scales Anger, Fear and Positive emotions/Exuberance that was between .74 to .79, based on ratings of 24 eight-year-old children administrated five weeks apart.

Data Collection and Procedure
Data collection was conducted during the fall of 2013, in connection with the assessment of the culturally adapted edition of PsPATHS curriculum. A complete revised assessment battery was used containing 12 cognitive tasks and, though not included in the present study, two observation studies of 2 to 3 children during joint play with two different toys. To counterbalance individual differences, the order of the
12 tasks was fixed. Motoric, verbal and computer based tasks were organized in a varied way to keep the children's interest. Results from six of these cognitive tasks were used in the present study. The Emotion Questionnaire were handed to preschool teachers, filled out and returned to researchers within the PsPATHS project. The preschool teachers were compensated with a cinema ticket for their contribution and the preschool with 500 Swedish Crowns for their participation.

All children were tested individually in a separate room at their preschool by two trained psychology students. During testing and observation one student acted as test leader and one kept score. Prior to each task the test leader explained the procedure to make sure that the child had understood the task, using pictures when required. The 12 cognitive tests were usually performed in two sessions over two days. Shorter or longer breaks during testing were taken when convenient. On the whole, a flexible attitude towards the children and towards the activity on the preschool was held. Out of consideration for the individual child, a test was terminated if the test leader sensed that a task was too difficult for the child or if the child explicitly did not want to participate.

Attrition
In cases where scores from the EF tasks or responses to the teacher questionnaires were missing, these separate variables were excluded from data processing. For the task Statue, cases with scores 8 and below was considered non-valid and were excluded in the analysis. Other reasons for attrition were children's absence from a session, malfunctioning materiel, i.e. when the internet connection with the computer tablet was interrupted, or that a test was terminated.

Data Processing
In the present study, the first research question was to examine how the measurements for EF components relate to each other and with teacher reports of ER in preschool children. For this, Pearson product-moment correlation coefficient were used.

The second research question, provided that significant correlations between EF and ER measurements were found, was to investigate if specific EF measurements give unique contribution to ER in preschool children. The intention was to use a Multiple regression analysis, with applicable measurements for EF as predictor variables and ER as outcome variable.

Results
In the present study and in this sample no significant correlations between EF and ER could be demonstrated, therefore, the second research question was not further explored.

Preliminary Data Analysis
Data was screened for outliers, i.e. deviating more than 3 SD from the mean and identified as extreme values in box plot. Eight outliers were identified; 2 for Go/No-go, 2 for Knock and Tap, 1 for Stroop, 1 for Word span and 2 for GSC Congruent.
Table 5. Descriptive Data for EF and ER Measures.

<table>
<thead>
<tr>
<th>Task and variable</th>
<th>N</th>
<th>M (SD)</th>
<th>Range</th>
<th>Skewness</th>
<th>Kurtosis</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Inhibition</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Statue</td>
<td>43</td>
<td>24.46 (5.30)</td>
<td>10.00 - 30.00</td>
<td>-1.23</td>
<td>0.88</td>
</tr>
<tr>
<td>Total correct responses</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Go/No-go</td>
<td>49</td>
<td>3.71 (3.81)</td>
<td>0.00 - 14.00</td>
<td>1.52</td>
<td>1.77</td>
</tr>
<tr>
<td>Total commission errors</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Knock and Tap</td>
<td>52</td>
<td>25.86 (3.20)</td>
<td>18.50 - 30.00</td>
<td>-0.97</td>
<td>0.19</td>
</tr>
<tr>
<td>Total correct responses</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Stroop</td>
<td>46</td>
<td>36.76 (6.06)</td>
<td>23.00 - 45.00</td>
<td>-0.69</td>
<td>-0.46</td>
</tr>
<tr>
<td>Total correct answers</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Working Memory</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Word span</td>
<td>53</td>
<td>11.84 (3.59)</td>
<td>4.00 - 19.00</td>
<td>-0.04</td>
<td>-0.48</td>
</tr>
<tr>
<td>Total correct responses</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Shifting</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Global Switch Cost - Congruent</td>
<td>51</td>
<td>12.23 (3.35)</td>
<td>5.00 - 20.00</td>
<td>-0.15</td>
<td>0.09</td>
</tr>
<tr>
<td>Global Switch Cost - Incongruent</td>
<td>51</td>
<td>8.94 (4.83)</td>
<td>-1.00 - 18.00</td>
<td>-0.48</td>
<td>-0.17</td>
</tr>
<tr>
<td><strong>Emotion Regulation</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>ER, Positive</td>
<td>55</td>
<td>3.66 (1.08)</td>
<td>1.00 - 5.00</td>
<td>-0.46</td>
<td>-0.61</td>
</tr>
<tr>
<td>ER, Negative</td>
<td>54</td>
<td>3.77 (1.04)</td>
<td>1.00 - 5.00</td>
<td>-0.71</td>
<td>0.11</td>
</tr>
<tr>
<td>ER Global</td>
<td>54</td>
<td>7.44 (1.82)</td>
<td>3.50 - 10.00</td>
<td>-0.32</td>
<td>-0.81</td>
</tr>
</tbody>
</table>

According to the winzorising method (Tabachnick & Fidel, 2001) these values were replaced with the next most extreme value within 3 SD. All variables met the standard criteria for univariate normality, skewness <3 and kurtosis <10 (Kline, 2009).

For the inhibition task Statue, 5 cases were considered as non-valid as the number of correct responses were below 8 points and these cases were excluded from further analysis. Descriptive data for all parameters are presented in Table 5.

**Data Analysis**

No significant correlations between measurements for ER and variables for EF were found, range from -.11 to .24 (all ps > .10).

Correlations between EF variables are presented in Table 6. Opposed to the expected result few significant associations were found between the measures for EF in this sample. Amongst inhibitory control variables, only Go/No-Go Total Commission Errors and Knock & Tap Total Score were significantly but negatively related (p < .01), i.e. children who performed well on the Knock & Tap task made less errors at the Go/No-
Go task. Stroop Total Correct Answers was marginally significant related to Statue Total Score \( (r_{40} = .29; p = .07) \) and to Knock & Tap Total Score \( (r_{45} = .27; p = .08) \).

Cognitive flexibility was expected to be most salient for the measure GSC for Congruent trials, but no significant correlations were found between GSC Congruent and other variables. On the other hand, GSC Incongruent trial, were significantly negatively related \( (p < .01) \) to Go/No-Go Total Commission Errors and significantly positively related to Stroop Total Correct answers \( (p < .01) \) and Statue Total Score \( (p < .05) \). Thus, for the preschool children in this sample, less difference between non-switch trials in the mixed condition vs. incongruent condition in the task Apples & Pears were associated with less errors on the task Go/No-Go, more correct answers on the Stroop test and to higher scores on the task Statue.

An analysis of missing cases showed that 21.8% of the cases were missing for the variable Statue Total Score, 16.4% for Stroop total correct answers and 10.9% of the cases were missing for Go/No-Go total commission errors. For all other variables, missing cases were less than 8%.

**Table 6.** Pearson product-moment correlation (two tailed), \( r \), for EF measurements.

<table>
<thead>
<tr>
<th></th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Statue Total Score (I)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Go/No-Go Total Commission Errors (I)</td>
<td>(-.04)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Knock&amp;Tap Total Score (I)</td>
<td>(.09)</td>
<td>(-.39^{**})</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Stroop Total Correct answers (I)</td>
<td>(.29)</td>
<td>(-.20)</td>
<td>(.26)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Word Span Total Score (WM)</td>
<td>(.22)</td>
<td>(-.22)</td>
<td>(.05)</td>
<td>(.22)</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>GobalSwitchCost Congruent (S)</td>
<td>(.16)</td>
<td>(-.27)</td>
<td>(.14)</td>
<td>(.06)</td>
<td>(-.10)</td>
</tr>
<tr>
<td>7</td>
<td>GlobalSwitchCost Incongruent (S)</td>
<td>(.32^{*})</td>
<td>(-.38^{**})</td>
<td>(.19)</td>
<td>(.34^{*})</td>
<td>(.23)</td>
</tr>
</tbody>
</table>

\(^{*} = p < .05\) \(^{**} = p < .01\)  Range N = 39-53

(I) = Inhibition, (WM) = Working Memory, (S) = Shifting
Discussion

The aim with the present study was to study the relation between different aspects of EF and ER in preschool children. It was hypothesized that there should be significant associations between the three EF components as well as between measurements of EF, especially inhibitory control, and regulation of positive and negative emotions. However, in this sample of four to five year old preschool children there were few significant correlations between EF components and no significant associations between EF and ER measurements. As a consequence, the second research question, i.e. if a specific EF measurement could give unique contribution to ER, was not further explored. The negative results may be a matter of methodology or, possibly, that the relation between EF and ER is not that evident in this sample of preschool children.

Aspects of measuring ER in preschool children

In the present study ER was assessed with a teacher questionnaire, with items capturing emotionality and regulation of intense negative (anger, sadness and fear) and positive (exuberance) emotions. Two items were used for regulation of positive emotions and negative emotions respectively, which may have been insufficient to capture the children’s ability to regulate emotions. Moreover, for the present study there was no multi-measurement approach, which is in contrast to other research of the relation between EF and ER. Carlson and Wang (2007) and Lieberman and colleagues (2007) used two different parent reports of ER in their studies, and demonstrated significant relations with the EF components inhibitory control and shifting respectively. Accordingly, for the present study a combination of teacher ratings and parent ratings could have broadened the picture of the children’s ability to regulate emotions. Also, as parents most likely take personal traits into consideration and observe their children’s ER in everyday situations, a similar design can also increase the ecological validity. On the other hand, Liebermann and colleagues (2007) argue that parental ratings may reflect a more general ER ability than specific ER measures do, which in turn can lead to lack of correlation between performance based and parental measures of ER.

Although out of scope for this thesis, there are other parameters worth mentioning that might have influenced ER in the preschool children in this sample. Amongst these are emotionality, i.e. how frequently and intensely emotions are aroused (Blair, 2002; Rydell et al, 2003), family context (Zimmermann & Thompson, 2014) but also parental care, parent’s own emotional expression and the child’s understanding of emotions (Camras & Shuster, 2013). Cultural views on how to express and perceive emotions can to a large extent influence children’s development of specific ways of regulating emotions (Cole, 2014). In this respect, cultural context could to some extent have had an influence on the variation in children’s ER in the present study as 14.5% of the children had a native language other than Swedish.

All together, it can be noted that the present study seems to have captured a limited aspect of ER. However, the variation present in the ER measures (see Table 5) indicated that there were individual differences in how the children in this sample could regulate intense positive and negative emotions.
**Associations between the EF components**

The measurements for EF in the present study were composed to cover the three core components, inhibitory control, WM and cognitive flexibility, in order to capture different aspects of EF. It was expected to find significant associations between the four measures of inhibitory control but also between the measures for the separate core components of EF. This was based on previous research performed by, for example, Brocki and Tillman (2014), Carlson and Wang (2007) and Libermann and colleagues (2007).

In the present study, a significant relation could only be demonstrated between two out of four tasks for inhibitory control. Children who performed well on the Knock & Tap task had significantly less errors on the Go/No-go task. This is in contrast with studies that have found associations in performance of different inhibitory control tasks. For example, Brocki and colleagues (2007) found significant relations (on the same set of tasks used in the present study) between Knock & Tap and Stroop and between Knock & Tap and Statue but no correlation with any of these tasks and Go/No-go. On the other hand, Brocki and Tillman (2014), in 5-14 year old children, found a significant association between performance on the same Go/No-go task used in the present study and an age-appropriate but comparable Stroop task.

The four inhibitory control tasks included in the present study covers different types inhibitory control that in turn require different cognitive processes and involves different responses. There are also differences in how performance on the tasks are registered. Accordingly, it could rather be the degree of complexity in inhibitory control that contributes to the association between Knock & Tap and Go/No-go, as the child in both tasks has to continuously recall and act on the present rule at every trial.

Moreover, the WM load also differs in the four tasks for inhibitory control. In Knock & Tap and Go/No-go there is a switch from one rule to another between the two blocks in the task, although WM was reduced with a visual cue in Go/No-go. In addition the child has to inhibit a prepotent response and produce an alternative response. For a preschool child this places great demands on WM (complex inhibition). On the other hand, for Statue the child only has to remember to keep his/her eyes closed and do nothing at all, regardless of what happens in the room (simple inhibition), and for Stroop there is only one rule - to say the opposite at all trials. However, the Stroop task can be considered even more complex in that a response conflict is activated when the child has to inhibit an already learned response (an upward pointing arrow means up) and verbally respond with the opposite word (down). Nevertheless, using multiple measures of inhibitory control is an advantage when inhibition is studied in preschool children.

The WM task used in the present study is considered a simple WM task and it was expected to find significant associations to other measures. Contrary to expectations, the measure for WM was not significantly related to inhibitory control or to any other EF (or ER) measure. This could mean that the task was either too simple or too difficult for the children, but descriptive data show that performance on the WM task was normally distributed in this sample. The non-significant relations rather suggest that WM is still under development during the preschool years and, accordingly, WM may not yet be sufficiently coordinated with other EF components. Indeed, a longitudinal study by
Brocki, Eninger, Thorell and Bohlin (2010) demonstrated that WM was significantly related to simple inhibition at age five and to complex inhibition at an age of six years, which indicate the effect of development.

Another possibility for the lack of significant associations in the present study is that the WM measure rather was a measure of short term memory (STM), in that information simply was held in mind rather than maintained and manipulated (Diamond, 2013). Further, in the present study verbal WM was measured and it is possible that another result would have been shown if a measure for visuo-spatial WM also were included. This is because non-executive processes (like speech, vision and perception of spatial objects) can have an influence on the performance (Best & Miller, 2010).

In the present sample cognitive flexibility was assessed by the computer based task Apples & Pears, based on the Dots task (Davidson et al., 2006). The results showed that most of the preschool children performed well in the congruent block (Apples) and that they could apply the "apple rule", i.e. to respond on the same side as the stimulus at the congruent trials within the mixed block. In addition, performance on the inhibition tasks Go/No-go, Stroop and Statue were significantly correlated with GSC Incongruent trials, i.e. the difference in performance on the incongruent trials within the mixed block (Apples & Pears) and the incongruent trial (Pears). Accordingly, the children could apply the "pear rule", i.e. to respond at the opposite side of the stimulus, in the mixed block and successfully switch between the rules in the mixed block. In fact, some children were even more accurate in the incongruent trials within the mixed trial than in the incongruent trial (see Table 5). Maybe, the intense demands in the mixed block made these children more attentive to the task. Taken together, in this sample cognitive flexibility was most distinct in GSC for incongruent trials. This was contrary to the expected result that cognitive flexibility in preschool children would be most salient in GSC for congruent trials, as reported in a study by Brocki and Tillman (2014). However, this was based on a larger age span (5 to 14 years) and GSC was not calculated separately for Congruent and Incongruent trials, but rather as an average of the two.

In the present study inhibitory control did not seem to be of importance for performance on congruent trials (Apples). Perhaps, performance on the congruent trials is more about keeping the rule in mind over the whole trial. Furthermore, most children in the present study performed on or above average on the inhibition tasks Statue, Knock & Tap and Stroop but had difficulties with performance on Go/No-go (see Table 5). However, performance on Go/No-go was the only EF measure that significantly correlated with GSC. This indicates that children with good inhibitory control were also good at cognitive flexibility.

From a developmental perspective, the EF components seem to have their own trajectory and, accordingly, the degree of coordination can vary from age to age. The results in the present study indicate that, for the children in this sample the EF components may not yet be sufficiently coordinated and therefore significant associations were scarce.
Methodological aspects

This thesis was performed within the research project PsPATHS where a number of abilities and aspects of preschool children’s development other than EF and ER were measured, e.g. social competence. Ethical permission was granted and standardized psychological measures with good reliability and validity was included for the data collection, which vouches for a solid research ground. However, the data set used in the present study was from the pre-study of PsPATHS and as the procedure for the data collection was still under development there was a certain instability in the measurements, e.g. in how the computer-based EF tasks were registered. There was also some uncertainty with regard to the teacher questionnaires as there was no information whether any teacher in the classroom filled in the form or if it was the teacher who knew the child best. This could have influenced the validity and reliability of the ER measurements and contributed to that significant associations not could be found.

Some remarks about the measures used in the present study have already been discussed but some need to be added. When a task designed to tap a specific EF component is performed, other EF components can be activated too, a problem often referred to as task impurity problem (Miyake & Friedman, 2012). In addition, many EF tasks usually require both executive functions and non-executive functions, like perception of colors and shapes, motor activity and speech (Brocki, 2007). Furthermore, performance on a monotonous, repetitive task also requires a considerable amount of attention. In the present study this could be evidenced by the amount of attrition, between 10% and 22%, for the three tasks for inhibitory control placed at the end of each test session. The children might have been tired and unfocused, or just bored, and maybe the performance on these tasks primarily reflects sustained attention rather than inhibitory control.

The shortcomings in methodology and the null-result in the present study raise the question whether the results rather reflect different aspects of the tasks included than of the specific abilities in the fifty-five children in this sample. With a larger sample latent variables could have been explored and used to control for methodological flaws. It is also possible that with a larger sample significant associations could have been demonstrated between EF components as well as between EF and ER. On the other hand, in the studies by Carlson & Wang (2007) and Lieberman and colleagues (2007), where significant relations between EF and ER were found, participant children were fifty-three and sixty respectively, which leads to the issue of differences in the composition of the samples.

For the samples in the present study and the studies mentioned above little is known about background variables, such as if the children were born full-term, number of siblings, parental education or other environmental parameters and experiences that possibly could influence the development of EF skills (Bierman et al., 2008; Zimmerman & Thompson, 2014). The children in the present study were recruited from three communities that differ in social-economical status and from private and municipal preschools, in order to get a good distribution in the sample. Still, it is possible that this sample of Swedish children was too homogenous and that restriction of range was an issue. In addition, differences in the test environment could have
influenced the children’s performance. Assessment of the children in this sample was performed at the preschools, whereas most studies earlier discussed were performed in particular play rooms at universities, which might have made the children more focused if they felt particularly important.

Another possible reason for the relative lack of significant associations could be if the range of distribution for the tasks in the present study was poor, but a closer look at the descriptive data for EF and ER measurements do not point in that direction. This narrows the differences to the specific tasks that were included and this is where the difficulties lie in comparisons of previous research. In this case a few issues are evident though.

In the study by Liebermann and colleagues (2007) parent ratings comprising EF’s and emotional control were included. In addition, in the study of preschool children by Carlson and Wang (2007) an ER Composite, comprising measures for suppression of positive and negative emotions and a measure of the child’s emotion understanding was used. However, in the present study no similar multi-measures was included. Therefore, adding a parent and/or teacher report of every-day EF could have increase the ecological validity in the present study.

Furthermore, only measures of the cognitive aspect of EF (cool EF) were included in the present study as previous research has shown distinct associations between these types of EF measures and ER. However, Zelazo and Carlson (2012) suggest that the motivational and affective aspect of EF (hot EF) may be of great importance for how a child responds in an upset situation. Carlson (2005) reported a significant age effect in preschool children for the EF task "Less is more", where children should infer that they should point to a smaller amount of treats in order to get the larger amount. This indicates that the ability to manage affective/motivational information evolves during the preschool years. On this basis, it is likely that the use of a performance-based affective EF task could have added the hot aspect of EF to the present study.

Language could also have been an issue in the present study as eight children had a native language other than Swedish. It is possible that these children had difficulties in understanding the instructions for the tasks, due to complexity or language, and consequently did not perform the EF tasks in a correct way. For the computer based tasks it is also possible that the children, irrespectively of language, found it difficult to grasp the instructions, but also that differences in children’s computer practice had an influence on the performance.

In spite of the discussed methodological shortcomings, the present study had a good approach in that measures for all EF components and several measures for inhibitory control were included. There was sufficient power in the sample but at the same time the high percentage of attrition in measures for inhibitory control probably had an impact on the result. On this basis, it is a delicate task to draw firm conclusions from the results in the present study, in that the study was performed on a relatively small sample and significant correlations were moderate in size. Nevertheless, the present study has given additional information about EF core components during the preschool age and
has brought up aspects that need to be further addressed when investigating how specific aspects of EF relate to ER in this age group.

**Future research**

One suggestion for future directions for developmental research of the relation between EF and ER is to perform a study similar to the present study, with suggested improvements and on a larger number of children, to explore if this could give more information. The age span could also be extended to include children of 3 to 6 years in order to be able to compare the relation between EF and ER in different age groups. The relation between different EF components as well as between EF and ER may be very different in different ages and, also, development of EF and ER is gradual and not stable over time. Therefore, it is of great importance to perform longitudinal studies to get a better picture of the development of EF and ER in preschool children.

In developmental studies of EF and ER the type as well as number of included tasks can differ a lot. Indeed, Blair, Zelazo and Greenberg (2005) emphasize the importance of increased precision in the measurements of EF in the study of development of self-regulation of emotions and behavior, i.e. ER. Many studies also, to different degrees, include a variety of slightly different EF and ER tasks, which makes it troublesome to compare the results and the interpretations of them. By using comparable tasks, applicable for a wide age-range, the possibilities to further map the developmental trajectories and common underlying processes would be broadened. Besides, the use of comparable tasks would also lessen the difficulties in comparing results from different studies.

It is also important to continue the efforts to unite cognitive-executive and affective-emotional aspects of self-regulation in developmental research, and search for common processes and associated neural networks that is involved in the control of behavior, thoughts and emotions. One way forward could be to combine cognitive tasks (cool EF), affective-motivational tasks (hot EF) and parental/teacher ratings of children’s self-regulation of emotions and behavior in order to capture more aspects of EF. Perhaps hot EF is even more developed than cool EF in preschoolers and could show a stronger relation with the ability to manage emotions, i.e. ER. This further points to the benefit of including measures for hot EF, as this can add information about to what extent measurements for hot EF correlate with measurements for ER in preschool children, if they in fact are "the same". In addition, brain imaging methods, like functional near-infrared spectroscopy (fNIR) technique, could be used to further extend the knowledge about the relation between EF and ER in young children.

Another area that needs to be considered in future studies is attention. Diamond (2013) has suggested attention to be an important factor for all EF core components that plays an important role in the relation between them. Perhaps attention even influences the relation between EF components in a way that a different pattern in the developmental relation between them would arise with increased attentional capacity. Garon and colleagues (2008) argue that "...if attentional processes are not yet integrated, EF tasks that vary in their dependence on different attentional processes would not be strongly correlated during the early preschool period." (p. 51). Attention is also considered an essential part of self-control which further indicates that attention also is important for
ER. Furthermore, Rueda, Posner and Rothbart (2005) has performed extensive research in the involvement of cognitive, temperamental and neural networks (called executive attention network) supporting attentional control in the emergence of self-regulation. In consequence, attention seems to be an important link between EF and ER and measurements for attention should preferably be included in future studies.

**Conclusion**

EF and ER are two complicated areas, especially when it comes to developmental research and in young children it can be difficult to distinguish emotion and cognition. During the preschool-years there are a substantial development in children´s EF and ER, but limited research has examined the relation between them. However, it has been established that EF´s are essential for cognitive, social and psychological development but also for future physical and mental health, success in school and in life. Consequently, it is important to help young children to have good EF´s and to acknowledge individual differences in young children´s ER, because older children with difficulties in regulating emotions are at risk for developing behavioral disorders. By finding out more about the relation between EF and ER it can be possible to find ways to detect children early on that are at risk for having difficulties with EF and ER. With somewhat unexpected results that affirm the complex puzzle of EF and ER abilities, the present study has contributed with further understanding in the relation between EF and ER in preschool children.
References


