Exploring the child Attentional Network Task

Associations with Day/night performance and individual differences in the behavioral inhibition system

Kristina Miljeteig

Master of Philosophy in Psychology

Cognitive Neuroscience

Department of Psychology

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Summary

This thesis was written by Kristina Miljeteig supervised by Else-Marie Augusti, with the title; "Exploring the child Attentional Network Task; suggested associations with Day/night performance and individual differences in the behavioral inhibition system". The thesis is a part of a larger study included in Else-Marie Augusti's post-doctoral project. All data was collected by Kristina Miljeteig along with one other master student. Additional data was collected in addition to the data included in the current thesis, and the other master student (Sunniva Stuvøy Heggen)'s thesis will focus on separate data. Students were also in charge of recruiting participants. Hypothesis development, data processing and statistical analysis was done independently. Participants were a sample of 28 children in their last year of kindergarten, recruited through child-care facilities throughout Oslo.

The aim of the thesis was to further investigate the properties of the child Attentional Network Task (ANT), and its use with preschool children (4-5 years), as recent studies have struggled to find consistent results in this age group (Forns et al., 2014; Ishigami & Klein, 2015; Rueda, Checa, & Combita, 2012). This was done through a within-subjects study (*n* = 28), utilizing among others the child ANT, a nonverbal Stroop-task, and parent-report measures of child temperament and behavioral motivation. The child ANT is a computerized experimental task where children are to indicate the direction of swimming fish, guided by different visual cues. The task is thought to measure three separate types of attention; alerting, orienting and cognitive control, and is recommended for use with 4-10 year old children (Rueda et al., 2004). While inhibition is closely related to several aspects of attention, it is believed to be most closely related to the cognitive control measure (St Clair-Thompson & Gathercole, 2006). Hence, associations between the ANT and a nonverbal Stroop-task were explored. In addition, performance on the ANT was compared to individual differences in the behavioral inhibition system, as measured through a parent-report scale. Regarding the properties of the task itself, the conclusion remains unclear as to whether the ANT is the optimal way to measure the different types of attention in preschool children. Clear scores were found for the orienting and cognitive control networks, but not for the alerting network. However, the cognitive control aspects of the study were found to be significantly related to inhibitory abilities as measured by the Day/night task. An association was also discovered between children of relatively high accuracy (>70 %) and parent reported behavioral inhibition system activation.

Acknowledgements

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Table of contents

1 Introduction

Executive functions develop greatly during childhood, involving the cognitive ability to plan, execute or inhibit actions (Bjorklund, 2005). These abilities are strongly involved in the regulation of attention (Bjorklund, 2005). One of the major functions of attention is the cognitive control of attention through selection of stimuli, and direction of action (Rueda, Posner, & Rothbart, 2005). As inhibitory abilities are important for cognitive control performance, the present thesis is focused on the relationship between cognitive control and inhibition performance together with individual differences in the behavioral inhibition system. The first chapter (1.1 - 1.4) will give an overview of the attentional networks as first proposed by Posner and Petersen (1989), how these networks are measured, and how they relate to inhibition and individual differences in the behavioral inhibition system.

The separation of attention in to three attentional systems was introduced by Posner and Petersen in 1989. Their evidence was based on a number of behavioral studies, as well as studies of patients with severe brain injuries (Petersen & Posner, 2012). Now, more than 25 years later, a great number of brain imaging studies have been able to confirm that there are indeed three separate attentional networks; the alerting network, the orienting network, and the cognitive control network (Petersen & Posner, 2012). Even though they are part of the same attentional system, these three networks seem to be capable of operating independently of each other (Petersen & Posner, 2012).

An experimental task called the Attentional Network Task (ANT) was developed as a means to measure the efficiency of these three networks in one simple and time-saving task (Fan, McCandliss, Sommer, Raz, & Posner, 2002). An adapted version of this task has also been developed for use with children from 4 to 10 years, which has been employed to investigate how the three different aspects of attention develop during childhood (Rueda et al., 2004). Studies have found separate developmental trajectories for alerting, orienting, and executive attention (Pozuelos, Paz-Alonso, Castillo, Fuentes, & Rueda, 2014). Nevertheless, the exact childhood development of the three attentional networks remains to be established (Ishigami & Klein, 2015; Rueda et al., 2004). In the present study, the ANT was used to look at the attentional networks in preschool children (4-5-year-olds). The ANT is currently recommended for use with children as young as four years of age, but few studies have focused on this particular age group. Moreover, some studies that have included a preschool sample have struggled to find consistent results (Forns et al., 2014; Ishigami & Klein, 2015; Rueda et al., 2012).

1.1 The Three Attentional Networks

The *alerting network* is perhaps the most intuitive of the attention networks. The concept of alerting is closely related to arousal, and is conceptualized as a way of obtaining and maintaining the optimal vigilance and activation needed to perform in a specific task, as well as a heightened sensitivity to incoming stimuli (Petersen & Posner, 2012). In the ANT, the alerting network is activated by providing a warning signal indicating when, but not where, the task-stimulus will occur (Fan, McCandliss, Fossella, Flombaum, & Posner, 2005). The alerting system is believed to be partially lateralized to the right hemisphere, involving the right temporal parietal junction, as well as a strong involvement from the thalamus (Fan et al., 2005; Petersen & Posner, 2012). Some left lateralized anterior and posterior cortical areas are also involved (Fan et al., 2005).

The *orienting network* is involved in selecting a location from where to prioritize sensory information (Rothbart, Posner, & Rosicky, 1994). This effect is most often produced and studied by presenting visual cues in a specific spatial location (Rothbart et al., 1994). Orienting is thought to develop quite shortly after birth. Indeed, when infants were engaged with a central stimulus, and another stimulus occurred on a monitor on their side, they oriented their attention towards the new stimuli in a very consistent manner already at four months of age (Rothbart et al., 1994). Some orienting-tests also involve a re-orientation of attention, where attention must be shifted from an invalid cue and onto the target stimulus. In these tasks, orienting has been found to develop until late childhood (Pozuelos et al., 2014). It is important to keep in mind that even though the orienting network is believed to be separate from the alerting network, they will most often co-occur in natural settings, as a natural stimulus is likely to give information both about the location and the timing of the target (Fan et al., 2002). The mapping of the anatomic base for the orienting network has turned out to be a bit more complicated, seeing as it involves the integration of sensory information. Mostly however, this involves the frontal eye fields, as well as the tempo-parietal junction, and the superior parietal lobe (Fan et al., 2005).

Cognitive conflict is perhaps the most studied of the three networks, and it is believed to underlie our ability to solve cognitive conflicts (Fan et al., 2002). It is sometimes referred to as the executive control network. Where both alerting and orienting typically involve automated mechanisms, executive control requires a conscious effort to solve a cognitive conflict, therefore employing the volitional aspects of attention. Different stimuli can trigger such cognitive conflicts. For instance, there can be a conflict between dimensions (like color and word), or it can be a conflict between relevant and irrelevant information. The most associated brain region is the Anterior Cingulate Cortex (ACC), which has been found to be involved in top-down selection and conflict monitoring (Fan, Flombaum, McCandliss, Thomas, & Posner, 2003; Fan et al., 2005).

1.2 Attentional Network Research in Children

1.2.1 Network Development

An adapted version of the ANT has been developed for use with children (Rueda et al., 2004). While the original task contained arrow stimuli, the child version of the task involves fish or other animals, pointing ("swimming") in different directions. The objective of the task, however, remains the same for both versions; to indicate the direction of the middle arrow/fish. The target stimulus is surrounded by either congruent or incongruent flanking stimuli. Spatial and non-spatial cues were incorporated for the test to be able to measure orienting and alerting, as well as cognitive control (Rueda et al., 2004). Rueda and colleagues (2004) originally hypothesized that the orienting network would be present and relatively stable from birth, while the alerting and executive control networks would develop during childhood.

In the first ANT-study of 6 to 9 year old children, Rueda and colleagues (2004) found that the orienting effects were the same across age groups (Rueda et al., 2004). Several later studies have demonstrated similar adult-like orienting effects in children from age 6 when using the ANT (Ishigami & Klein, 2015; Mezzacappa, 2004). In the ANT, orienting is measured by subtracting spatial cue trials from center cue trials. As the target stimuli never occurs in the center, the center cue only gives information on when the target will appear. The spatial cue, on the other hand, gives information on both when and where the target will appear, which should yield lower reaction times (RTs). While the orienting effect may be stable from birth

(Rothbart et al., 1994), it might not be as easily measured by the ANT at such a young age (Rueda et al., 2012). Indeed, in an attention-training study including 5-year-old children, several of the obtained orienting scores were negative, or just slightly positive (Rueda et al., 2012). A negative score is an indication that the children actually have shorter RT's when the central cue is presented, than when a spatial cue is presented. If this is the case, the children were not able to utilize the spatial information provided by the cue. This is not in line with the original claim made by Rueda and colleagues (2004), and could indicate a potential limitation for this specific type of orienting manipulation for preschool children (Ishigami & Klein, 2015).

The alerting network is also believed to be quite stable during childhood (< 10 years), and alerting effects found for children were generally much larger than in adults, illustrating how children generally benefit more from alerting cues (Rueda et al., 2004). This tendency in alerting network scores has been replicated on several occasions (Mezzacappa, 2004; Pizzo et al., 2010). In a more recent study focused upon network development, a progressive reduction in alerting score was seen already from age 8 when using an auditory alerting cue (Pozuelos et al., 2014). Following this, the alerting effect should ideally be even larger for preschool children, than for school aged children. Research on preschoolers, however, has indicated that the results of the cueing conditions may not be as straightforward as suggested in the original research (Ishigami & Klein, 2015; Rueda et al., 2012; Rueda et al., 2004). The abovementioned attention-training study by Rueda and colleagues (2012) failed to find the expected alerting effects in the pre-test, where both the control group and the training group displayed very small effects for the alerting network. As with the orienting effect, the measured alerting effect in the ANT relies upon the children's abilities to interpret and utilize the visual cues given in the task.

Displaying a more robust development than the two other networks, the cognitive control network showed drastic improvements from age 6 to age 7, before stabilizing in both RTs and accuracy rates (Rothbart, 2007; Rueda et al., 2004). This has been replicated in numerous studies, in which young children have consistently shown large cognitive control scores (Forns et al., 2014; Pizzo et al., 2010; Rueda et al., 2012). Other conflict studies have also found great improvements in conflict resolution from age 3 to age 7 (Rueda et al., 2005). Children as young as 3 years were generally able to execute spatial conflict tasks with quite high accuracy, while demonstrating the cognitive conflict effect through lower accuracy rates on incongruent trials (Rothbart, 2007). According to an ERP-study by Rueda and colleagues (2005), there seems to be a general tendency that the involved brain circuits in conflict tasks are distributed across a larger area in young children, becoming more centralized and focal as conflict resolution improves.

1.2.2 Child ANT Properties

One of the most vital findings from the study by Rueda and colleagues (2004) was the consistent lack of correlation between the three networks in the entire sample of differently aged children. This has been used as a rationale for the different networks' ability to operate independently of each other. When investigating executive function in a sample of pre-term children between 5,5 and 6,5 years of age (Pizzo et al., 2010), researchers were, like Rueda and colleagues (2004), able to confirm independent network scores for both the control group and the pre-term group. However, the orienting and control networks were significantly more correlated in the pre-term group (Pizzo et al., 2010). Other studies have investigated the relationship between the three networks through ERP and EEG recordings, discovering some age-dependent interactions where both alerting and orienting in some cases modulated executive attention (Abundis-Gutiérrez, Checa, Castellanos, & Rueda, 2014). Still, the networks are believed to be mostly independent (Abundis-Gutiérrez et al., 2014). Rueda and colleagues (2004) concluded that the child ANT was a fairly effective and reliable way to measure attentional networks in children from age 4. However, in the aforementioned experiments, Rueda and colleagues (2004) only used participants from 6 years and older. Hence, the stability of these networks in 4-5 year-old children seems to be an assumption based on preliminary data, and cannot be verified by this work alone.

Regarding the reliability and robustness of the ANT as a network assessment tool, a compilation of Spanish ANT-studies put together by Forns and colleagues (2014) reviewed network results for a little under 3000 children. They concluded that robust results were only available for the executive control network, as both the orienting and the alerting networks displayed poor internal consistency (Forns et al., 2014). In an even more recent attempt to investigate the robustness and reliability of the child ANT, Ishigami and Klein (2015) administered the ANT to a group of children for ten individual sessions. Their results yielded low reliability scores for all three networks, making them question the use of the ANT in young children, especially in studies that require repeated testing. However, their subjects were 12 children ranged from 5 years 10 months, to 7 years 9 months (Ishigami & Klein, 2015), which is a quite modest sample size even for repeated testing. These results can therefore not alone determine the use of the child ANT within these age samples.

As previously mentioned, cognitive control as an executive function construct is believed to be highly dependent upon inhibitory processes. From developmental research we know that these constructs are interrelated, working together to guide behavior and attention in young children (Rothbart, Ellis, Rosario Rueda, & Posner, 2003; Rueda et al., 2005). Some researchers have gone so far as to propose that inhibitory abilities are imperative to being civilized human beings, and that inhibition is the single most important quality possessed by humans (Tangney, Baumeister, & Boone, 2004). The following paragraphs will discuss different aspects of inhibition, and how they relate to cognitive control and the ANT.

1.3 Inhibition

The construct of inhibition has been conceptualized in different ways by many different paradigms (Nigg, 2000). Most researchers agree, however, that inhibitory mechanisms play a crucial role in executive control (Brainerd & Dempster, 1995; Nigg, 2000; Rueda et al., 2005). Interference control is one of the most studied inhibitory mechanisms, and may involve the suppression of distracting information, behavioral inhibition as well as working memory abilities (Montgomery & Koeltzow, 2010; Nigg, 2000). In the current study both the congruent/incongruent Flanker task and the Stroop-like Day/night task were regarded as measures of interference control. The process of interference control can be divided into three steps: (1) maintaining the rules of the task need over a series of trials, (2) inhibiting a dominant response in relation to a particular stimulus, and (3) selecting and executing a subdominant response (Montgomery & Koeltzow, 2010). The classic Stroop task is believed to be the most established measure of interference control (Brainerd & Dempster, 1995; Nigg, 2000). Essentially, the Stroop effect is what happens when it takes longer to name a color-word when the word is printed in the ink of a contrasting color (Nigg, 2000).

As the cognitive control network is measured by subtracting RTs on congruent trials from RTs on incongruent trials, as with a traditional Flanker task (Fan et al., 2002; Posner & Petersen, 1989), the cognitive control network can be seen as a measure of interference control as well. The interfering flankers are though to prime a pre-potent (but incorrect) response that needs to be inhibited while another subdominant response is selected and executed (Nigg, 2000). On the other hand, inhibitory tasks like the Go/no-go task only require a quick response when a certain stimulus is presented, as well as the ability to inhibit that same response when another stimulus is presented, thereby measuring the most basic form for behavioral inhibition. The Go/no-go task does not require the selection and execution of a subdominant response, as required by the Stroop task.

In adults, the Stroop effect depends heavily upon the ACC. Similarly, Fan and colleagues (2005) found that activation in the ACC as well as left and right frontal areas was associated with executive control in a Flanker task. Another study by Fan and colleagues (2003) found similar activations in the ACC and lateral PFC across three different conflict tasks, including the color-word Stroop task and the Flanker task as well as a spatial conflict task. Although similar brain activations were seen in all three tasks, Fan and colleagues (2003) failed to find any significant behavioral correlations in conflict performance (measured through RTs). This could indicate that the tasks may have been relying on different conflict resolution resources after all. An alternative explanation is that the ACC is in charge of conflict monitoring, and not the specific conflict resolution itself (Fan et al., 2003). This connection has not, however, been as thoroughly investigated in children.

Inhibition is thought to mediate attention by controlling the execution of behavior (Rueda et al., 2005). This inhibitory influence interacts with individual differences in temperament, and especially self-regulation. Self-regulation, in turn, is important for the construct of "effortful control", defined by Rothbart and colleagues (2003) as "the ability to suppress a dominant response in order to perform a subdominant response" (p. 1114). According to Rueda and colleagues (2005), interference control is also closely related to effortful control. Consistent individual differences in effortful control are seen as temperamental differences (Rothbart et al., 2003). When individual levels of inhibition influence behavior in a consistent manner this is often attributed to two separate motivational systems, referred to as behavioral inhibition- and behavioral activation-systems (Carver & White, 1994). These systems are separated from effortful control; effortful control is seen as a more controlled process, whereas BIS/BAS drive behavior in a more instinctive and affectively loaded way (Rothbart et al., 2003).

1.3.1 Behavioral Inhibition and Behavioral Activation Systems

BIS and BAS are two separate motivational systems, which operate individually of each other. This means that it is possible for an individual to have a high score of both the BIS and BAS systems, as well as any other combination (Gray, 1972). In general, the BAS is responsive to appetitive stimuli, and serves as a drive to approach behavior through reward sensitivity and goal-directedness (J. A. Gray & McNaughton, 2003). The BIS, on the other hand, is responsive to aversive stimuli, and causes avoidance behaviors, often leading to fear or anxiety. As these systems work independently of each other, they often conflict to control behavior (J. A. Gray & McNaughton, 2003). Both systems have been found to have a strong neural basis and a quite unique ability to predict multiple factors like well-being, anxiety, and internalizing problems (Coplan, Wilson, Frohlick, & Zelenski, 2006). The original publication on these systems by Gray (1972) was a modification of Eysenck's popular dual personality theory, suggesting a biological base for the personality traits extraversion-introversion. Similarly, Gray's model of approach-avoidance motivation was largely based on the same biological systems (Gray, 1972). This approach-avoidance conflict seems to be rooted in the phylogenetically old "fight or flight" system. New studies have indeed found that high BIS sensitivity was able to predict symptoms of anxiety, negative affectivity as well as other socio-emotional dysfunction (Coplan et al., 2006; Taubitz, Pedersen, & Larson, 2015). In general, it has been harder to find equal predictive power of BAS sensitivity, but the sub-division of BAS into three separate factors, has made such studies more fruitful (Taubitz et al., 2015). The three sub scores are: BAS-Drive, BAS-Fun Seeking, and BAS-Reward responsiveness. They are seen as separate, but interacting constructs. Taubitz and colleagues (2015) found that reward responsiveness was the most adaptive of the three, and highly related to psychological well-being across multiple domains.

A recent study by Lamm and colleagues (2014) was able to relate individual differences in BIS/BAS tendencies to performance on a Go/no-go task. As mentioned, the Go/no-go task is a task that requires cognitive control through behavioral inhibition. Lamm and colleagues (2014) found a positive correlation between high BIS and RT on the no-go-trials. In short, the more inhibited children had longer RTs, but higher accuracy (also when controlling for a trade-off between the two). Nonetheless, it remains undetermined how generalizable this finding is. As it is believed that both the Stroop- the Flanker and the Go/no-go-task relies upon a similar ability to solve cognitive conflict, there is a possibility that the results from Lamm and colleagues (2014) could be replicated by using the ANT.

1.4 Study Aims and Hypotheses

The current study had three different aims along with their specific hypotheses:

1) The first aim was to explore and analyze the development of the three attentional networks in preschool children. How established are the three different networks in 4 to 5-year-old children, and how well will the ANT be able to measure network efficiently in this particular age group?

Hypothesis 1: Drawing on more recent research which is consistent with the age group targeted in the present study (Forns et al., 2014; Rueda et al., 2012), it seems unlikely that stable orienting and alerting results will be found by using the ANT in the current sample of preschool children. Accordingly, hypotheses 1a and 1b state that consistent effects of orienting (1a) and alerting (1b) will be hard to establish. In regards to the executive control network, this effect has been shown to be both large and stable across studies and age groups (Forns et al., 2014; Pizzo et al., 2010; Rueda et al., 2012; Rueda et al., 2004). Therefore, a quite large effect of the executive control network is expected (Hypothesis 1c).

2) The second aim was to investigate whether different measures of inhibition were related the sample of preschool children. Is conflict performance (measured by the ANT) related to inhibition in a nonverbal Stroop-task?

Hypothesis 2: Although studies with adults have failed to find a link between conflict performance as measured by the ANT, and inhibition tasks, studies with children indicate that the inhibitory and conflict abilities are less specialized in children. The current study therefore predicts an association between task performances on these two measures (Hypothesis 2).

3) The third aim was to discover whether individual differences in the behavioral inhibition system were associated with different response patterns in the ANT.

Hypothesis 3: Lamm and colleagues (2014) found that higher BIS sensitivity was related to a higher accuracy on the no-go trials. They also found a positive correlation between BIS and RT on the go-trials. These results could possibly be transferrable to the ANT, due to the fact that both the no-go trials and the incongruent flanker trials are believed to rely upon inhibitory control. From this, the current study predicts that accuracy on the incongruent flanker trials will improve with heightened BIS sensitivity, and that BIS also will be associated with longer RTs (Hypothesis 3).

2 Methods

2.1 Participants

Children and their parents were recruited through their child care facilities. The child care facilities were contacted by the researchers, and asked to participate in the study through distributing information to the parents as well as providing a suitable test environment. The participants were children in their last year of kindergarten (n = 28) aged 4-5 years (mean age 64.6 months). There were 17 boys and 11 girls. One girl was excluded due to missing ANT-data, thus, the final sample for the ANT-analysis included 27 children.

All parents provided written consent prior to testing, and the study was approved by a regional ethics committee (REK). A majority of the children came from families with high socioeconomic status, and nine (33%) of the children received the highest SES-score, indicating that both their parents have 5-6-year university degrees and a joined income exceeding 1 000 000 NOK.

2.2 Research Procedure

This research was part of an extensive longitudinal study on child maltreatment and executive functions. The current study included non-maltreated children only. All participants went through the same test battery, making this study a within-subjects design. Participants were tested in a quiet, separate room provided by each kindergarten. They were tested either from 09:30-11:00, or from 11:30-13:00. After testing, a selection of questionnaires was sent home to the parents.

The entire testing procedure lasted about 1.5 hours, including breaks. The children were encouraged to take breaks, drink water, and play with their friends. Procedure 1 consisted of the ANT, followed by a non-verbal pattern test from WIPPSI, an emotional as well as a non-emotional Stroop test, a word definition test from WIPPSI, and lastly, another version of the ANT. The entire procedure was partially counterbalanced, that is, a reversed version of the procedure was administered to half the children. This was done to minimize practice effects, boredom effects or other confounding carryover effects. For the present thesis, only the ANT, the Day/night task and the parent-report BIS/BAS scale were included. Some demographic variables were also included in the preliminary analysis, such as age, gender and a socioeconomic status -variable.

2.3 Cognitive Measures

2.3.1 The Attentional Network Task (Rueda et al., 2004).

The ANT was originally developed by Fan and colleagues (2002) as a way to measure the effectiveness of the three attentional networks in one cohesive task. The different conditions are thought to influence RTs in different ways, making it possible to discern the three individual attention networks through RT analysis. The ANT has later been adapted for use with children (Rueda et al., 2004), and the current study used a modified version of this child ANT. In the child version of the task, the original arrow targets and flankers have been exchanged for bright yellow fishes. The children were introduced to a narrative surrounding the task, where the objective was to catch the *middle* fish (Rueda et al., 2004). The child version of the ANT also gave feedback to the child for each trial, as a way to increase task engagement. Research has shown that children perform better when given feedback, and when there is a clear narrative surrounding the task (Berger, Jones, Rothbart, & Posner, 2000). The conditions of the child ANT were the same as in the adult ANT, with four different cue types (see Figure 1), as well as neutral, congruent and incongruent flanker trials. Several studies have chosen to omit the neutral flanker condition, as the results are consistently equivalent to the results with the neutral flankers (Abundis-Gutiérrez et al., 2014; Rueda et al., 2012). In the current study, only congruent and incongruent flanker conditions were included (see Figure 2). On the congruent trials, the flanker fish swims the same way as the target (middle) fish. On the incongruent trials, the flanker fish swims the opposite way from the target (middle) fish.

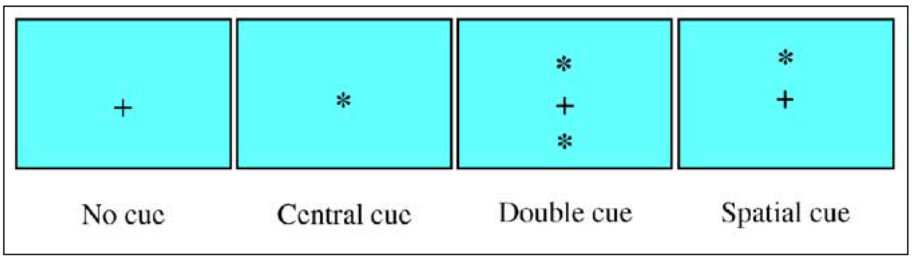

Figure 1:The four cueing conditions from Rueda and colleagues (2004).

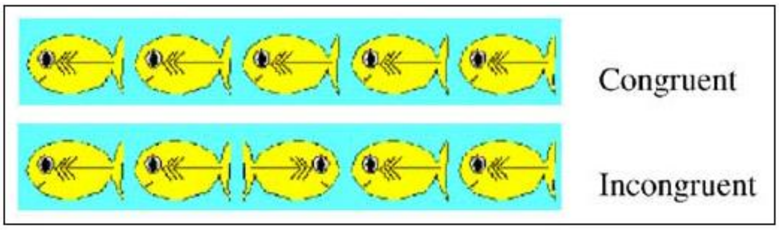

Figure 2: The congruent and incongruent trials from Rueda and colleagues (2004).

Due to the fact that testing was conducted in different kindergartens, the ANT was completed on a DELL laptop, with a standard 15" screen. The laptop was placed on a table in front of the child, and adjusted to a comfortable height. No restrictions were put upon participants' movements. Responses were made on the right and left mouse button on the laptop. Corresponding arrow notes were attached to the response buttons. The test was adapted and administered using E-Prime version 2.0 (Psychology Software Tools Inc., Sharpsburg, PA).

Before the task started, the children were presented with 8 practice trials. The children were encouraged to catch the middle fish as quickly and accurately as they could, by indicating which direction the fish was swimming. In the practice trials, the children received praise and encouragement. The practice trials had no time limit, and the children were able to repeat the trial session for as many times as needed for them to understand the task. None of the current participants needed to repeat the practice block. The experiment itself consisted of four blocks, two with fish as the main stimuli, and two with birds. Each block consisted of 32 randomized trials, 16 congruent and 16 incongruent with 8 trials for each cue (half of which were incongruent and half of which were congruent).

All trials followed a similar procedure (see Figure 3). First, a fixation cross was presented in the middle of the screen for a duration of 400ms for the cued trials, 500ms for the no-cue trials. Subsequently for the cued conditions, one of the cues in the shape of an asterisk was presented for 100ms, followed by another fixation period of 450ms. After the fixation period, the flanker fish and the target (middle) fish was presented for 3000ms. Both correct and incorrect responses terminated the trial, initializing the feedback screen. Feedback for correct responses was a "wohoo"-sound accompanied by an animation of the fish/bird being trapped in a hand-held net. Commission or omission errors yielded a low "beep"-sound, and no animation. After each block, a picture of many fish in a bowl was presented alongside an encouraging text. The entire test lasted no longer than 12 minutes.

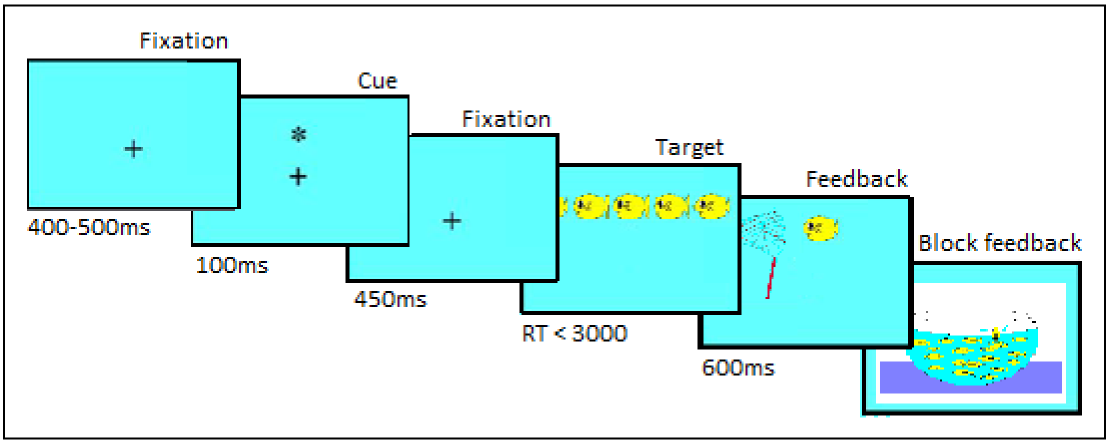

Figure 3- A flowchart describing the current trial procedure.

2.3.2 The Day/night Task (Lagattuta, Sayfan, & Monsour, 2011).

The Day/night task is a nonverbal version Stroop task, developed to measure interference control in 3 to 7-year-old children. The main reason why the Day/night task was included in the present study, was to investigate whether there is a link between Stroop performance and Flanker performance. In 2011, a new version of the Day/night task was made with revised stimuli, to facilitate even greater control over the saliency- and shape-aspects of stimuli presentation (Lagattuta et al., 2011). The current study used these revised stimuli cards from Lagattuta and colleagues (2011), which were 20 rectangular laminated cards where ten of them display the sun while the other ten display a full moon and stars (See Figure 4).

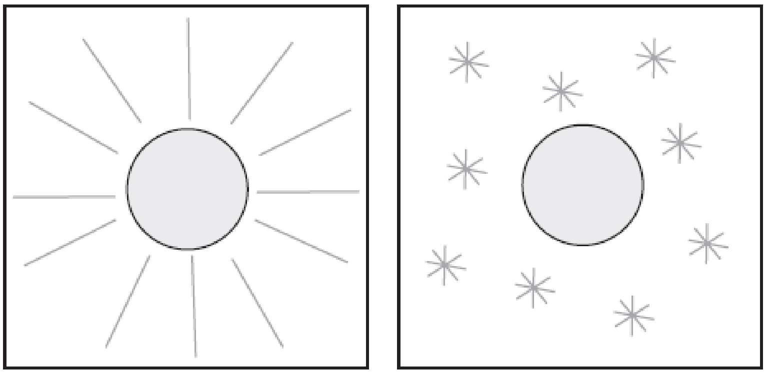

Figure 4: Revised Day/night stimuli from Lagattuta and colleagues (2011).

The task itself was presented as “the opposites-game”. Participants were instructed to say “day” when presented a card portraying a full moon and stars, and to say “night” when presented with a card portraying the sun. Participants practiced until they got four correct answers in a row, containing at least one double presentation. After the practice session, the children were presented with 20 cards in a row, with no feedback. Rules were only repeated if the child gave four wrong answers in a row, or seemed to have forgotten the rules of the task. Cards were presented in two equally randomized sequences, varying with procedure. Both accuracy and total time spent on the task was recorded. Self-corrections as well as whole syllables that were part of the incorrect response counted as an incorrect response. In the present study scores were verified by two separate raters.

2.4 Measures of Individual Differences

2.4.1 BIS/BAS

The current study utilized a parent-report questionnaire to assess the children’s individual levels of BIS and BAS sensitivity. This 20-item measure was developed by Carver and White (1994), and later adapted into a parent-report scale (Blair, Peters, & Granger, 2004). The parent-report measure has been validated in several studies investigating its physiological and behavioral correlates (Blair et al., 2004). In the current study a Norwegian translation was used, but some examples of items from the original English version were: ‘‘If my child thinks something unpleasant is going to happen, he/she gets pretty worked up,’’ and ‘‘My child feels pretty worried when he/she knows someone is angry with him/her’’ (Blair et al., 2004, p. 116). The parents rated their child’s behavioral motivation on a Likert-scale from 1 (completely disagree) to 7 (completely agree).

When studying this age group of young children, a four-factor model, including BIS, BAS-Reward, BAS-Fun Seeking and BAS-Drive has been proposed as a better fit to describe the data (Kingsbury, Coplan, Weeks, & Rose-Krasnor, 2013). However, some researchers have found that the Cronbach alpha coefficient (α) measuring the internal consistency of the scale was higher for the BAS-dimension as a whole, and have therefore chosen to utilize this instead (Blair et al., 2004). In the current study, the BIS subscale was of an acceptable consistency, $\alpha = .74$. This α value was an identical to the one obtained by Carver and White (1994) in the original development of the scale. The overall BAS consistency of the current study was also good, with a Cronbach alpha value of .82. Carver and White (1994) only reported the reliability of the three BAS sub-factors, which were .73 for BAS reward, .76 for BAS Drive and .66 for BAS Fun. The alpha values obtained in the current study were the same or stronger than the originally reported alpha values (Carver & White, 1994) with .78 for BAS Reward, .87 for BAS Drive and .66 for BAS Fun. Only the BIS scale was included in the current study.

2.5 Statistical Analysis

2.5.1 Socioeconomic Status

Some demographic variables were included in the parent-report leaflet. To be able to include socioeconomic status (SES) in the preliminary analyses, an SES variable was created. This variable was computed through assigning a 1-7 value to income and a 1-6 value for education level. Sum scores were made for both parents before dividing this sum by two. The maximum obtainable SES was 13, and the current sample ranged from 5.5 to 13. The sample mean was 11.62, and 9 out of 27 children (33 %) attained the maximum SES-score.

2.5.2 Preliminary Data Processing

All data processing was completed using Microsoft Excel (2010). In analyzing the ANT-data, the mean of the median scores was used for each condition. This has been done quite consistently when using ANT data from young children (Abundis-Gutiérrez et al., 2014; Ishigami & Klein, 2010; Mezzacappa, 2004; Pizzo et al., 2010; Rueda et al., 2004). It is also recommended to use the median when handling RT-data with large variations such as in the present study, due to its robustness as a central tendency measure (Whelan, 2008). Before calculating the medians for all response categories, responses below 200ms were removed. The same was done with response times exceeding 3 standard deviations (*SD*s) above the means for each cue x flanker -category. Responses shorter than 200ms were most likely made before the child had actually considered the task (Whelan, 2008). Similarly, responses exceeding 3 *SD*s above the category mean were most likely due to inattentiveness rather than task demands (Whelan, 2008). Cut-offs were made individually for each condition, to minimize the risk that the chosen cut-off would bias the results. This was done individually for each participant.

Omission errors were not included in any of the RT or accuracy variables; however, a correlational analysis was executed to see whether commission errors and omission errors were related. If the children that have many omission errors also have many commission errors, one can assume that no valuable information about performance would be lost when excluding the omissions from the computed variables. Furthermore, it seems to be standard procedure across studies to exclude omissions from the analysis (Pizzo et al., 2010; Rueda et al., 2012; Rueda et al., 2004).

Subtraction scores were made in accordance with the original research by Rueda and colleagues (2004). The orienting network score was computed by subtracting the center cue condition RTs from the spatial cue RTs, collapsed across flanker conditions. Alerting was computed by subtracting the double cue condition from the no cue condition, also collapsed across flanker conditions. Executive control was measured by subtracting the congruent trial RTs from the incongruent trial RTs, collapsed across cue conditions. As an extra validation of the network scores, subtraction scores were made for percent accuracy as well.

2.5.3 Data Analysis

All statistical analyses were executed using SPSS version 22. (SPSS Inc., Chicago, IL, USA) All tests were two-tailed, and *p*-values were considered statistically significant when $p < .05$. Effect sizes were reported in terms of eta-squared, and described as specified by Cohen (1992). All reported correlational analyses were Pearson product-moment correlation coefficients, and the same guidelines were used when describing the Pearson product-moment correlations as were used for the effect sizes (Cohen, 1992).

Included in the preliminary analyses were a series of one-way Analyses of Variance (ANOVAs) and correlational analyses, performed so as to rule out any effect of gender, age, SES, or researcher on any of the main variables. A preliminary analysis also investigated the independence of the three networks through a correlational analysis.

Regarding the development and stability of the three attention networks, main effects of cue and congruency on RT and accuracy were investigated using one-way ANOVAs. To investigate the Hypothesis 2, and also as a means to validate the results of the flanker effect, a correlational analysis was performed between Day/night accuracy and accuracy on incongruent ANT-trials. Only incongruent trials from the ANT were included in the analysis, due to the fact that the Day/night task only included incongruent stimuli. To investigate Hypothesis 3, regarding individual differences, a correlational analysis was performed with parent-report BIS score and accuracy on incongruent trials as well as RT on incongruent trials. A regression analysis was performed to further investigate to what degree BIS-score was associated with accuracy on incongruent trials.

3 Results

3.1 Preliminary Analysis

No values approaching significance were found for gender, age, SES, or researcher, and for this reason these variables were not included in any of the main analyses. The exception was one significant gender difference for orienting, which will be presented under "subtraction scores".

A preliminary investigation confirmed that the three networks seemed to be independent from each other. Indeed, Pearson's product moment correlations were almost nonexistent. This was the case for the conflict and alerting correlation ($r(25) = .002$, $p = .993$), for the conflict and orienting correlation ($r(25) = -.005$, $p = .982$), as well as for the alerting and orienting correlation ($r(25) = -.153$, $p = .447$).

Furthermore, the overall accuracy was significantly correlated with RTs ($r(25) = -.399$, $p = .039$), indicating that there was a moderate negative relationship between accuracy and the overall response time, which was to be expected. This means that there was not generally a trade-off between speed and accuracy, but rather, that the children that had many errors also had longer RTs.

3.2 ANT

3.2.1 Subtraction Scores

Following the subtraction guidelines from previous studies, mean rates for each of the three networks were computed, which can be seen in Table 1. The *alerting score* was computed by subtracting the trials with a double cue from the trials with no cue. The *orienting score* was computed by subtracting the trials with a spatial cue from the trials with a center cue. The *conflict score* was computed by subtracting the congruent trials from the incongruent trials. Subtraction scores were also calculated for accuracy. These subtractions for accuracy followed the same procedure as the regular subtraction scores.

Table 1

Network subtraction scores for reaction times and accuracy (*SD*)

	Alerting	**Orienting**	**Conflict**
Reaction times (ms)	- 28.46 (156.94)	67.20 (135.81)	147.43 (143.37)
Accuracy (% points)	0.59 (5.3)	- 0.88 (7.9)	6.84 (12.5)

From the preliminary analysis, a significant gender difference was discovered on the orienting network score. The one-way between subjects ANOVA showed a significant effect of gender; $F(1, 25) = 6.76$, $p = .010$, $\eta^2 = .213$. The mean subtraction score for the boys (n =17) was 20.06ms (SD = 98.66), while the mean network score for the girls (n = 10) was 147.35ms (SD = 156.98). The mean difference in orienting was 127,29ms. The current sample was slightly uneven, with only 37 % girls included in the current sample. Due to the lack of homogenous groups, an ANOVA with Welch's *F* was used as a more robust statistic to further clarify the relationship between the groups. The analysis revealed that the gender differences were still significant; $F(1, 13.3) = 5{,}336$, $p = .038$.

3.2.2 Accuracy

Overall mean accuracy was 93.3 % (SD = 7.6), excluding omissions. Mean omission rate was 7.6 % (SD = 7.3). Omission errors were strongly negatively correlated with percent accuracy (r (25) = -.750, $p < .001$), meaning that the children with a high number of omission errors, also had low accuracy (that is, a high number of commission errors).

3.2.3 Main Effects

A one-way ANOVA showed large main effects of congruency (flanker type) on both RTs (F (1, 26) = 31.32, $p < .001$, $\eta^2 = .077$) and accuracy rates (F (1, 26) = 7.62, $p = .010$, $\eta^2 = .104$). This shows that children were significantly slower and less accurate on incongruent trials. No significant effects were found for cue type on either RT (F (3, 78) =.87, $p = .461$) or accuracy (F (3, 78) = .76, $p = .522$). Very small effect sizes were found for both RT ($\eta^2 = .003$) and accuracy ($\eta^2 = .006$). There were no significant interactions between cue and congruency on RT (F (3, 78) = .67, $p = .574$) or accuracy rates (F (3, 78) = 1.20, $p = .316$). Correspondingly small effect sizes were found for both RT ($\eta^2 = .002$) and accuracy ($\eta^2 = .095$).

Accuracy rates for the different cue x flanker -categories can be viewed in Table 2, the mean RTs for the same categories can be viewed in Table 3.

Table 2

Mean accuracy in % (*SD*)

Flanker type	Cue type			
	No cue	Center cue	Double cue	Spatial cue
Congruent	98.2 (4.3)	97.3 (4.2)	95.6 (7.2)	95.0 (9.8)
Incongruent	90.1 (14.4)	89.3 (13.1)	90.4 (16.4)	90.0 (14.3)

Table 3

Mean of median RTs in ms (*SD*)

Flanker type	Cue type			
	No cue	Center cue	Double cue	Spatial cue
Congruent	1367.56 (499.74)	1367,25 (484.92)	1375,15(481.53)	1337,02(478.79)
Incongruent	1507,95 (555.33)	1549,59 (537.04)	1493,20 (500.36)	1521,72 (516.45)

3.3 Measurement Associations

To investigate whether there was an association between ANT and Day/night performance (Hypothesis 2), a correlational analysis was performed on the overall accuracy of incongruent trials and Day/night performance (both in %). Mean accuracy on the Day/night task was 81.0 % (*SD* = 10.7), mean total time spent on the task was 51.8 seconds (*SD* = 10.1). There was a significant correlation between overall accuracy on the Day/night task and accuracy on the incongruent ANT trials ($r(25) = .488$, $p = .010$). This can be described as a quite solid correlation, indicating that children who had a high accuracy on the Day/night test also performed well on the incongruent flanker trials. On the other hand, children who performed poorly on the Day/night test also performed poorly on the incongruent flanker trials.

A similar analysis was conducted between overall time spent on the Stroop task, and mean RT on the ANT. No values approaching significance were found. Because Day/night RT was collected on task level, only total time in seconds was available for analysis, not trial-based RTs.

3.4 BIS

To investigate the hypothesis on behavioral inhibition (Hypothesis 3), a correlational analysis was performed on the BIS score and the accuracy of incongruent trials. A Pearson product moment correlation found no significant relationship between the variables when all participants were included in the analysis (r(25) = .274, *p* = .167). Upon inspection of the scatterplot, however, there seemed to be a linear trend among the subjects with an accuracy level above 70 %. The mean incongruent accuracy was 89.9 %. A correlational analysis confirmed that there was a significant positive relationship between the variables (*r*(20) = .487, *p* = .034) when only including accuracy levels above 70 %. A linear regression analysis was performed to further explore this association, revealing a significant predictive ability of BIS on the accuracy of incongruent trials (β = 0.29, *F* (1, 20) = 5.283, *p* = .034), with an R^2 value of .237. According to this model, participants' predicted accuracy is equal to 82.3 + 2.9 (BIS-scale points) percent. Participants' average accuracy increased by 2.9 % for each point on the BIS-activation scale (as rated by their parents).

Following the example by Lamm et al. (2014), RT was included in the following regression analysis to make sure that the relationship between BIS and accuracy rates on incongruent trials was not simply due to a speed-accuracy trade-off. The results of the step-wise linear regression analysis were consistent with the first analysis (β = 0.487, *F* (1, 17) = 5.283, *p* = .034), showing that the differences in accuracy were non-related to the differences in RT.

To investigate the relationship between RT on incongruent trials and individual differences in the BI-system, a correlational analysis was conducted. No significant correlational relationship was discovered between RT and accuracy on incongruent trials (*r* = .249, *p* = 0.290), although a small positive correlation was discovered between the variables.

4 Discussion

4.1 Main Findings

The main goal of this study was to investigate the use of the Attentional Network Task (ANT) in preschool children, and secondly, whether there was a relationship between conflict performance as measured by the ANT and performance on a Stroop-like Day/night task. The third aim of the current study was to investigate whether there was an association between parent-report BIS-activation and performance on the ANT. The orienting effect obtained by the current study was larger than hypothesized, and corresponded more with the original results (Rueda et al., 2004) than the more recent results from Rueda and colleagues (2012). Hypothesis 1a was therefore not supported. The alerting score obtained in the current study on the other hand, was even smaller than anticipated from earlier studies, which supports Hypothesis 1b. As expected, preschool children performed significantly better on congruent than incongruent trials, and this difference was found to be larger in the current sample of preschool children than what has been discovered in children a year older (Rueda et al., 2012). This is in line with the hypothesis on the executive control network (Hypothesis 1c). In support of Hypothesis 2, a significant correlation was found between Day/night accuracy and the accuracy of the incongruent ANT-trials. As a means to investigate the last hypothesis (Hypothesis 3), a correlation and a regression analysis revealed a non-significant relationship between BIS score and accuracy on incongruent trials when including all participants. This analysis failed to support Hypothesis 3. Yet, a significant result was discovered when introducing an accuracy cutoff level of 70 %. No relationship was discovered in terms of RTs.

4.2 Network Scores

When it comes to the orienting network (Hypothesis 1a), the obtained mean score was quite high – in fact, it was on the same level as the youngest children tested during the original development of the child ANT (Rueda et al., 2004). This finding was a little surprising, as the training study by Rueda and colleagues (2012) used an age span quite identical to the one in the current study, where the first sessions failed to obtain even positive subtraction scores for the orienting network. Other studies have also failed to find sufficient orienting effects in this particular age group (Ishigami & Klein, 2015). One possible reason for these findings, could be the increase in sample size in the current study compared to Rueda and colleagues (2012). According to Ishigami and Klein (2015), orienting effects were only found when a great number of trials was added to the analysis (in their case, collapsed across several sessions). The current study's increase in sample could therefore play an important role in the findings for the orienting network.

The orienting network also displayed an unexpected gender effect. Girls had significantly larger orienting scores, indicating that the girls in the study performed better when a spatial cue was provided. While it could be possible that this age (4-5 years) represents a critical age for how these cues are interpreted, and that this development occurs earlier in girls, it does not seem very likely. Taking into consideration the uneven gender samples, it is not possible to conclude anything as to the validity of these results. The one-way ANOVA requires even samples (Cohen, 1992), which was lacking in the current study. Also, as already discussed, the variance in this age group was very high, and likely to contribute to the current findings, especially given the small sample of girls in the present study. To my best of knowledge, no other studies have discovered any gender effects on the orienting effect. For instance, the large-scale study by Forns and colleagues (2014) found no consistent gender effects on orienting across nearly 3000 subjects. Incidentally, it has been found that boys generally have faster RTs than girls on different attention tasks, while girls have higher accuracy rates (Forns et al., 2014; Sobeh & Spijkers, 2013). However, no results approaching significance were found for either accuracy rates or RTs in the present study.

The mean alerting score obtained in the current study was negative, and while some difficulty was expected in obtaining a robust accuracy score (Hypothesis 1b), a negative alerting score was not predicted. Although the high variance displayed with this age group could make the subtraction scores less stable, it still seems unlikely that this negative score was due only to large individual variations. In the aforementioned training study by Rueda and colleagues (2012), the pre-test of both the control group and the training group revealed very low alerting scores. These modest alerting scores, combined with the high *SD*s, indicate that a sizable portion of the subjects had negative subtraction scores when subtracting the double-cue trials from the no-cue-trials. In other words, some of these children have shorter median RTs when no cue is presented at all, which is what was also found in the current study. According to Rueda and colleagues (2012), the lack of significant training effects on the alerting network was due to the high variability of the data, as well as reaching a "probable" ceiling level. Still, the results from the last posttest showed that the control group and the training group had very similar alerting sores (Rueda et al., 2012). These results indicate that the improvement cannot be attributed only to the implemented training program. Perhaps repeating the test three times was sufficient for the control group to reach some sort of ceiling level, or it could be that the three test runs were what was needed for the children to learn the task properly. Training effects have indeed been found in the early sessions for young children (Ishigami & Klein, 2015).

There were large effects of flanker congruency on both accuracy and RT, which was well in line with earlier research, and also in accordance with Hypothesis 1c. This difference between congruent and incongruent trials is believed to decrease with age, as the children become more competent in solving cognitive conflicts (Rueda et al 2004). Considering the tendencies of previous studies, the conflict score obtained in this study fell perfectly in line with the proposed developmental pattern of the conflict network (Rueda et al., 2012; Rueda et al., 2004). The mean conflict score in the current study of 4- to 5-year-old children was substantially higher than that of Rueda and colleagues (2004). They found that the score decreased further in 7 year-old children, where it stabilized at an adult level (Rueda et al., 2004). The current finding was not surprising, as the conflict network is believed to be the network that is measured in the most consistent and stable way by the ANT (Forns et al., 2014).

4.3 The Cue Conditions

Neither significant effect of cue, nor any significant interaction between cue and flanker was discovered in the current study. According to the original developers (Rueda et al., 2004) a main effect of cue should be expected. However, more recent research on the specific age group in question suggests that this effect might not be as strong as predicted (Forns et al., 2014; Rueda et al., 2012). Several recent studies involving preschoolers fail to include any main effect of cue in their report, without explicitly explaining why this is left out (Pizzo et al., 2010; Rueda et al., 2012). Indeed, for a substantial amount of participants in the current study, the no-cue condition used in the alerting subtraction score was the condition with the lowest RTs of all categories. The fact that many children have lower response times when no cue is presented at all supports the notion that preschool children were not able to utilize the cues properly. As the mean age of the current study was nearly identical to that of Rueda and colleagues (2012), this should also be the case for the cue conditions in the training study. Unfortunately, no cue scores are reported in their article, nor do they give any indication of whether there was a significant main effect of cue in the study. Upon inspection of their mean network scores and *SD*s it seems unlikely that any large effects of cue were present. The same is true for the study by Pizzo and colleagues (2010), where the means of some of the cue conditions vary by only a few milliseconds. As indicated by studies with older children, alerting effects are generally much higher in children than in adults (Rueda et al., 2004). It therefore seems unlikely that a decrease in alerting score reflects superior performance in the preschool children (compared to older children). Recent EEG-data in combination with response times on the child ANT suggest that young children have poor abilities in processing warning signals (Abundis-Gutiérrez et al., 2014). It might be the case that the subtle cues provided by the child ANT was not sufficient to produce the desired effect in such young children. It should be noted that the *SD*s in both the current study, as well as in other studies (Rueda et al., 2012; Rueda et al., 2004) were quite high. In several of the conditions and age groups reported in Rueda and colleagues (2012), the *SD*s were many times higher than the calculated mean score itself. This indicates a very large individual variation including both positive and negative subtraction scores. Undoubtedly, this variation could make the mean scores less stable, as well as harder to replicate. It should also be noted that the mentioned training study included only 37 children, divided into two groups (Rueda et al., 2012). The calculated scores from the training and control group consist of only 18 and 19 observations. However, in a large-sampled study (n = 2904) aimed to assess the reliability and internal consistency of the ANT, Forns and colleagues (2014) conclude that only the conflict network obtained robust scores. If this is the case even for such great samples, it should not be surprising that we struggled to find consistent results for the two other networks with such a modest sample size.

When considering the orienting scores described in Rueda and colleagues (2012), there were greater discrepancies between the training and control group in the pre-test, than in any of the following post-tests. Although a quite high subtraction score for orienting was found in the current study, this inconsistency could be a cause for some concern. Upon inspection of the unexpected gender difference found in the current study, the male group (n = 17) displayed a subtraction score more in line with the scores obtained by Rueda and colleagues (2012). The male group also displayed a smaller *SD*, indicating a greater degree of stability. As there is no theoretical reason why the orienting network should be less effective in 4 to 5-year-olds than in 5 to 6-year-olds, the discrepancies between the two groups in Rueda and colleagues' (2012) study already in the pre-test could point to a degree of instability in the test itself. As mentioned earlier, several studies that have tested the stability and robustness of the ANT have failed to find satisfactory results for the different attention networks (Forns et al., 2014; Ishigami & Klein, 2010; Ishigami & Klein, 2015). These issues seem to magnify with decreasing age. Although we know that orienting to exogenous cues develops already during infancy (Rothbart et al., 1994), the same is not true for taking advantage of the predictability of spatial cues (Enns & Brodeur, 1989). In a study of how predictive and non-predictive cues were utilized in groups of 6- and 8-year-old children compared to adults, neither the 6- nor the 8-year-olds were able to utilize the predictive spatial cues to any measurable advantage (Enns & Brodeur, 1989). Hence, the child ANT in its original form might not be the most suitable tool to measure the orienting effect in preschool children.

4.4 Cognitive Control and Inhibition

According to Mezzacappa (2004), a correlation between Stroop performance and Flanker performance as measured by the ANT would strengthen the validity of any potential findings using the child ANT (Mezzacappa, 2004). The current study discovered a strong link between performance accuracy on these two tests, using the Day/night test as a nonverbal Stroop option. An anatomical link between these types of tasks was established by Fan and colleagues (2003) in a conflict fMRI study with adult subjects. While the ACC was involved in all three conflict tasks, behavioral evidence indicated a substantial degree of independence between the tasks (Fan et al., 2003). Also focusing on adults, a study by Huizinga and colleagues (2006) attempted to determine a common underlying factor for three inhibition tasks; namely the Stroop task, the Flanker task, and a Stop-signal task. All these three tasks required motor inhibition of a pre-potent response; however, the researchers found only weak or slightly negative correlations in their analyses (Huizinga et al., 2006). On the other hand, studies of conflict task activation in children and adults have shown that children's activation patterns were less focal and more general than adults (Rueda et al., 2005). Additionally, these activations seemed to become more specialized as conflict resolution improved (Rueda et al., 2005). In support of this, Ven, Kroesbergen, Boom, and Leseman (2013) failed to distinguish between inhibitory and shifting (to shift between a mental set of rules) abilities in 6-year-old children, using a variety of tasks. These two functions have been quite easily distinguished in adults. The researchers therefore argued for a shared conflict resolution factor within executive function for young children (Ven et al., 2013). Taken together, this evidence could indicate that children's cognitive control network seem to be less specialized than adults, which could be part of the reason why such a strong relationship between conflict tasks is discovered with children and not adults. After all, brain plasticity has been found to play an important role in the development and training of cognitive control and inhibition (Rueda et al., 2005).

4.4.1 The Behavioral Inhibition System

The study by Lamm and colleagues (2014) revealed a correlational relationship between no-go trials on a go/no-go task, and a highly activated behavioral inhibition system. This relationship has to my best of knowledge not been investigated before with the ANT, although it has been suggested for further research by Mezzacappa (2004). Although no significant association was found between children that were high on BIS-activation and accuracy rate on incongruent trials, a significant relationship was discovered when a cutoff rate (70 %) was introduced for accuracy. It is hard to speculate in whether this signifies a significant relationship between the variables or not. On one hand, there is a possibility that the children with a very low accuracy rate on the incongruent trials simply have not developed the necessary inhibitory skills needed to perform sufficiently on the incongruent flanker trials. Inhibition is found to develop greatly throughout childhood (Brydges, Anderson, Reid, & Fox, 2013; Coplan et al., 2006). On the other hand, one could argue that large variations are natural in such a young sample, and therefore all children should be included in the analysis. Hence, this study was not sufficient neither discard nor confirm the hypothesis (Hypothesis 3) that there is a relationship between children that are rated as high on BIS, and conflict performance.

If there is a link between BIS-activation and conflict performance, the reason for this association remains uncertain. One possibility could be that the children with highly activated BIS have a more developed cognitive conflict network. According to the study by Lamm and colleagues (2014) the predictive abilities of BIS on go/no-go performance was not correlated with brain activation. They therefore suggested that the reason why BIS performance was associated with no-go accuracy was that the children that were high in BIS activation actively over-controlled their behavior. This behavior was supposedly nonrelated to the differences in brain activation (Lamm et al., 2014). If this was the case, then a hypothetical association with the ANT would not necessarily mean that the children high in BIS used their attentional networks differently, but rather that they over-controlled their behavior, thereby reaching higher accuracy levels. This should in turn be related to longer RTs, as was the case in the Go/no-go study (Lamm et al., 2014). BIS was related to higher RTs on the Go- trials, even when controlling for accuracy. In the case of Lamm and colleagues (2014), this further strengthened their claim that high BIS led to a behavioral change, where the over-controlling of behavior lead to longer RTs on all trials. In the current study there were no significant correlations between BIS and RTs. However, upon examination of the scatter plot, there seemed to be a clear tendency towards a positive linear correlation between BIS score and RT on incongruent trials. As previously discussed, the individual variations in median RT were very large, ranging from under 1000ms, to over 2000ms. Due to this large spread, it is possible that a larger sample is required to obtain significant results on RTs.

4.5 Limitations

Significant main effects were found only for the congruent and incongruent flanker conditions, and not for cue type. There are several possible explanations why the cue types did not significantly affect response times. It is possible that task engagement was simply too low for the cue effect to appear. Earlier studies have found that boredom affected ANT performance in young children, accounting for some of the large variability in the data (Ishigami & Klein, 2015). However, the current study obtained large and consistent effects of flanker congruency, and furthermore, the flanker effects were significantly correlated with Day/night performance. This makes it less likely that task engagement itself was too low to produce results.

Another possible reason for the lack of significant cueing effects is the differences in cue onset. In the original ANT, the fixation period before the cue appears was randomized between 400ms and 1600ms. In their case, the alerting cue provides more temporal information than when the fixation time is set more closely. However, this does not explain why several other studies who include larger variations in cue onset also fail to find any main effects of cue (Pizzo et al., 2010; Rueda et al., 2012).

In regards to the individual differences measure, some researchers have advised against using the ANT to correlate network scores with individual measures due to the low reliability of the scores (Ishigami & Klein, 2015). It is therefore likely that a large trial sample is needed to obtain significant results on individual difference measures. However, several studies have shown that the cognitive control network is more robust and reliable than the two other network scores (Forns et al., 2014), and for that reason, a collapsed variable for all incongruent trials was used in the current study.

As to why no significant effect of high or low BIS was found on performance on incongruent trials, there were some factors in the current study that differed from the study by Lamm and colleagues (2014). Our measure of BIS sensitivity was a parent-report form, while Lamm and colleagues additionally used behavioral observation to assess the behavioral inhibition system. They also used the CBQ – "Child Behavior Questionnaire" in addition to the CBCL. In support for using only the parent-report questionnaire, Blair and colleagues (2004) have provided substantial evidence that parent-report questionnaires were highly effective in measuring BIS sensitivity, and that such measures were indeed able to predict neurophysiological functioning. A more relevant issue is the differences in the inhibition task itself. While Lamm and colleagues (2014) used a simple Go/no-go task, the current study utilized performance on the incongruent flanker trials of the ANT. Other studies have failed to find a behavioral link between these types of tasks (Fan et al., 2003; Huizinga et al., 2006), although they seem to rely more upon common structures during childhood (Rueda et al., 2005). Thus, it might well be that BIS is more related to the pure measure of behavioral inhibition compared to interference control as measured by the incongruent flankers in the ANT. Another possible reason for the lack of significant results could be the great variation displayed in both accuracy and RTs in the present study. When the mean accuracy of the incongruent trials is close to 90 %, and some children have accuracy rates of 40-60 %, it seems unlikely that this entire discrepancy was due only to individual differences in temperament. Similarly, median RT's varied with more than a second between subjects, making it hard to correlate RT with the BIS rating, which was done by adults on a 1-7 scale. Possibly this would be easier with a sample size adapted for a between-subjects design where one could compare high and low BIS children.

As mentioned when discussing the training article by Rueda and colleagues (2012), small sample sizes can be problematic when the variance in RT is as substantial as seen here. Still, the current sample of 27 in a within-subjects study is larger than several published studies on the child ANT (Ishigami & Klein, 2015; Rueda et al., 2004). Additionally, the compilation study by Forns and colleagues (2014) failed to find any robust results even with their sample of almost 3000 children.

Another possible issue with the current sample is diversity. Because participation was voluntary, the sample was largely compiled of children from upper middle class families. It has been established that low SES children perform poorer on a variety of executive function-tasks, including inhibitory tasks (Aran-Filippetti & Richaud de Minzi, 2012). Another study found that SES was related to RT in the ANT (Mezzacappa, 2004). This might have been found in the current study if low SES children were included in the sample. As the current study is mainly within-subjects, this lack of diversity should not affect the current results.

5 Conclusions

The flanker effect remained stable when testing preschool children, and seemed to have robust influences on both RT and accuracy. Thus, the present study contributes in strengthening the proposed developmental trajectory of this particular network. The discovered correlational relationship with Day/night performance works to further strengthen the validity of the measure. Additionally, it strengthens the belief that both tasks rely upon common abilities, at least in young children. Studies with adults have shown that these types of tasks evoke a common neuroanatomy, although these structures seem to become more specialized with age and improved conflict performance (Rueda et al., 2005). This points towards to a strong relationship between different types of cognitive inhibition and interference control, at least in preschool children. The proposed link to temperamental inhibition is neither confirmed nor rejected by the findings of this study, although some indications pointing in the direction of a relationship were established. A study designed solely focused on this link is advised to clarify this relationship, preferably between-subjects.

The orienting and alerting networks have proven to be harder to measure in a consistent way with the ANT. This study, while obtaining acceptable orienting effects, was not able to strengthen the support for the use of the ANT as a means for investigating the alerting network in preschool children. Further studies should focus on possible improvements that could be made to optimize the use of the ANT with young children. Particularly, a fruitful focus could be how to improve the way the cues are given in the task. Some studies have experimented with auditory cues, but the optimal cue stimuli to use with preschool children remains still to be discovered.

6 Literature List

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