Language and executive functioning in children with ADHD
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Most of the studies on language problems of children with ADHD are descriptive in nature (see Section 2.2.2). That is, the language problems go unexplained. As mentioned in Chapter 1, the exception is the work by Tannock and Schachar (1996). They go beyond a pure description of ADHD children’s language and theorize that:

‘(...) executive dysfunction may account for both the core behavioural problems and the pragmatic disorders commonly observed in ADHD’ (Tannock and Schachar 1996: 145).

In other words, Tannock and Schachar propose that linguistic symptoms of ADHD are caused by non-linguistic factors. In the literature, executive dysfunctioning is often linked to the behavioral symptoms of ADHD (e.g. Pennington and Ozonoff, 1996), but not specifically to the pragmatic language symptoms.

First of all, executive functioning will be introduced in Section 3.1. Section 3.2 will discuss executive functioning in abnormal development, in particular in children with ADHD and in children with SLI. Section 3.3 will focus on the relation between executive functioning and language (more specifically: on pragmatic aspects
of language). Finally, Section 3.4 will recap the two research questions from Sections 2.4 and 3.3, and will also introduce the third research question. Moreover, the general expectations for all three questions will be provided.

3.1 INTRODUCTION TO EXECUTIVE FUNCTIONING

Executive functioning is an umbrella term, encompassing several interrelated higher order cognitive processes. Together, executive functions enable self-control and are responsible for:

‘(...) the ability to maintain an appropriate problem solving set for attainment of a future goal.’ (Welsh and Pennington, 1988: 201).

Executive functions are needed for many everyday activities, especially non-routinized situations, such as organizing a family activity, meeting a friend downtown, doing the groceries etcetera (Huizinga, 2006: 87-124). In general, multiple steps with intermediate results are involved in such situations. Moreover, adequate responses to these steps and results are necessary (Shah and Miyake, 1999). There is considerable debate as to how many executive functions can be distinguished. Traditionally, Pennington and Ozonoff (1996) discriminate between five executive functions: inhibition, working memory, planning, cognitive flexibility and non-verbal fluency. In this thesis, we will use measures based on this taxonomy, which can be applied to study normal and abnormal development in executive functioning (Geurts, 2003: 163-174).

Executive functions are strongly associated with the prefrontal cortices of the brain, and their neural networks (Pennington and Ozonoff, 1996). Different regions within the prefrontal cortices underlie different components of executive functioning (e.g. Aron, Robbins and Poldrack, 2004; Narayan, Prabhakaran, Bunge,
Cristoff, Fine and Gabrieli, 2005; Crone, Wendelken, Donohue and Bunge, 2006). The prefrontal cortices develop during childhood, adolescence and young adulthood (e.g. Casey, Tottenham, Liston and Durston, 2005; Amso and Casey, 2006). Thus, executive functions develop simultaneously with the prefrontal cortices, and, as a consequence, executive functioning becomes more efficient as children grow older. Moreover, executive functions do not develop at the same rate; mature levels of performance on different executive functioning tasks are reached at different ages (Diamond, 2002; Welsh, 2002). Huizinga, Dolan and Van der Molen (2006) studied Dutch children’s executive functioning (7, 11, 15 and 21 years old). They also found evidence for different developmental trajectories of several executive functions. For example, the development of shifting continued into adolescence, i.e. 15 years of age, and working memory continued to develop into young adulthood, i.e. 21 years of age.

3.2 Executive functioning in children with ADHD and SLI

This section will discuss non-verbal executive functioning in ADHD children (Section 3.2.1), and in SLI children (Section 3.2.2). The focus will be on inhibition, working memory, planning, cognitive flexibility and fluency, as these are the executive functions discriminated in the taxonomy of Pennington and Ozonoff (1996). However, before doing so, some methodological issues concerning the measurement of executive functioning will be addressed.

An executive functioning task is a complex task that assesses many interacting component processes. Pennington and Ozonoff (1996) mention four important problems in the measurement of executive functioning: (1) the tasks are not theoretically well-specified, (2) they do not allow the identification of different
component processes, (3) they are not always reliable and normally distributed, and (4) they do not appear to be sensitive to the same underlying processes across the range of performance. These measurement problems all contribute to what Pennington and Ozonoff call the ‘discriminant validity problem’. That is, executive function deficits are seen in various disorders, not only in ADHD, but also in, for example, conduct disorder, autism, and Tourette syndrome. Executive function deficits are at least a correlate, and possibly also a cause of the disruptions in complex behavior in these disorders. This would imply that these disorders all involve a dysfunction of the prefrontal cortices. However, the question that Pennington and Ozonoff raise is how such a single deficit in the prefrontal cortices leads to such symptomatically different complex behavior disorders. Pennington and Ozonoff therefore propose that level and profile differences should be sought on executive functioning measures across disorders to at least partly solve the ‘discriminant validity problem’.

Such methodological issues should be kept in mind when reading Section 3.2.1 about executive functioning in ADHD and Section 3.2.2 about executive functioning in SLI.

3.2.1 Executive functioning in ADHD
The review by Pennington and Ozonoff (1996) showed that 15 out of 18 studies found significant differences between ADHD subjects and controls (in the age range of 6 to 24-year-old) on one or more measures of executive functioning. A total of 60 different executive functioning measures were used across studies. The ADHD group performed significantly worse on 40 of these measures, and on no measure better. Pennington and Ozonoff concluded that (motor) inhibition is the main executive functioning deficit in ADHD. However, they also found problems on measures of working
memory, planning, and cognitive flexibility, although these findings were inconsistent across the studies reviewed.12

Sergeant, Geurts and Oosterlaan (2002) reviewed performance of various clinical groups (4 to 40 years of age) on a number of executive functioning measures. Although they did find performance deficiencies in ADHD, most notably in inhibition, and less so in working memory, planning, cognitive flexibility and non-verbal fluency, no consistent pattern emerged between the different clinical groups. There did not appear to be a specific executive functioning profile for ADHD. Geurts, Verté, Oosterlaan, Roeyers and Sergeant (2004b) compared executive functioning in Dutch children with ADHD, children with high functioning autism and typically developing children (6-13 years of age). In general, children with higher functioning autism exhibited more profound problems than children with ADHD. However, ADHD children performed worse than typically developing children on measures of inhibition and verbal fluency.

According to Barkley (1997a, b, c), behavioral inhibition indeed is the primary executive functioning deficit in ADHD. In his model, this inhibitory deficit would in turn lead to other, secondary, executive functioning deficits. It is one of the most elaborate and comprehensive models of executive functioning in relation to ADHD. However, Willcutt, Doyle, Nigg, Faraone and Pennington (2005; also see Willcutt, Sonuga-Barke, Nigg and Sergeant, 2008) conclude in a meta-analytic review of the validity of the executive functioning theory of ADHD that executive functioning weaknesses in children and adolescents are neither necessary nor sufficient to explain the behavior of all cases of ADHD. However, they also state that difficulties with executive functioning, most notably in inhibition, but

12 More detailed results about the performance of ADHD children on specific tasks/outcome variables will be discussed in Chapter 6. In this section, we mostly focus on the five executive function domains in general.
also in working memory and planning, are an important component of the complex neuropsychology of ADHD.

As a point of interest, several studies, e.g. the study by Kempton, et al. (1999), show that executive dysfunctioning in ADHD children is improved by stimulant medication.

In sum, the reviews and studies discussed in this section all point to a problem with (motor) inhibition in ADHD. Problems with non-verbal working memory, planning, cognitive flexibility and fluency are also reported, but the findings are not consistent. The ‘discriminant validity problem’, put forward by Pennington and Ozonoff (1996), cannot be solved on the basis of these studies. That is, it is still unclear how specific the executive functioning deficits are, and whether or not profile and level differences can be distinguished.

3.2.2 Executive functioning in SLI
Two different kinds of accounts try to explain the language problems in children with SLI. On the one hand, modular accounts, for example within the generative framework, claim that children with SLI have a defective innate grammar. The focus is on competence and representation. One of the problems is that they in general predict more severe grammatical deficits than that are actually seen in children with SLI. On the other hand, and more relevant for this study, non-modular accounts treat grammatical deficits of children with SLI as secondary to more general perceptual deficits, or deficits in, for example, working memory. These accounts focus on performance and processing. The fact that children with SLI show a partial mastery of grammatical rules supports such accounts. We will adopt a non-modular perspective in this study, also because the working hypothesis assumes an association between pragmatic
language and executive functioning, at least in children with ADHD (Tannock and Schachar, 1996).

This section will review the findings for the same five executive functions in SLI: inhibition, working memory, planning, cognitive flexibility and non-verbal fluency. Furthermore, we will try to establish whether or not level and profile differences, specific for SLI, can be distinguished (Pennington and Ozonoff, 1996). As of yet, there is no comprehensive review of the performance of SLI children on the five executive functions that have been so prominently researched in ADHD. Rather, different authors focus on different models in order to explain SLI children’s language problems. Working memory usually plays a central role in these models, as well as attention13.

Attention is often impaired in children with (S)LI. For example, a recent review of Ebert and Kohnert (2011) demonstrated substantial evidence for the occurrence of sustained attention deficits in LI children (3-20 years of age). Attentional control is also impaired in children with SLI (7-12 years of age), as has been demonstrated by Im-Bolter, Johnston and Pascual-Leone (2006). It should be noted that attention in ADHD research is generally not considered to be an executive function, although executive functioning does overlap with domains such as attention (Pennington and Ozonoff, 1996). Perhaps somewhat counter-intuitively, the deficit in attention in ADHD is not seen as a deficit in attentional capacity, because ADHD children do not appear to have deficits on tests of divided, selective or sustained attention (Sergeant and Van der Meere, 1990). Rather, the deficit is seen as one of attentional control, due to a failure to inhibit processing of, or responses to stimuli that are relevant to a task (e.g. Roodenrys, 2006). As a consequence, the ADHD literature seems to

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13 An example is Cowan’s (2001) model of attention and memory, discussed in Gilliam, Montgomery and Gilliam (2009).
separate the research topics (i.e. attention on the one hand and executive functions on the other) more clearly than the SLI literature.

Many children with SLI exhibit significant working memory deficits relative to same-age peers (e.g. Montgomery, 2002). Most of the working memory research is based on the model of Baddeley (Baddeley, 1986; Gathercole and Baddeley, 1990; 1993; Baddeley, 2000). This model of working memory consists of several parts: the phonological loop, the visuospatial sketchpad, the episodic buffer and the central executive. The central executive is domain general and responsible for attentional control and regulation14. The phonological loop and the visuospatial sketchpad are domain specific and responsible for the temporary retention of, respectively, verbal material and visuospatial material. The episodic buffer is a relatively new component in the model (also see Baddeley, 2003); it is able to integrate input from both so-called slave systems (i.e. phonological as well as visuospatial input) into one coherent representation. Gathercole and Baddeley (1990) proposed that part of the language problems of children with SLI is attributable to poor phonological short-term memory. According to the authors, new linguistic material is placed in the phonological loop. The phonological representations in this loop fade quickly, unless reactivated through rehearsal. Only then does the material enter long-term memory. Problems in phonological short-term memory may be responsible for the below-age vocabularies of children with SLI. Moreover, it is possible that they adversely affect the comprehension of grammar as well as lexical verb learning (Gathercole and Baddeley, 1993). A considerable amount of research, reviewed by Leonard (2000), supports these claims. A

14 The central executive in this model encompasses several of the five executive functions in the taxonomy by Pennington and Ozonoff (1996; see Section 3.2.1), such as inhibition and cognitive flexibility.
more recent review by Montgomery, Magimairaj and Finney (2010) also showed that SLI children, in comparison with same-age peers, demonstrate problems in all components of the working memory model of Baddeley. For Dutch LI children (5 years of age), problems in working memory are reported too (Van Daal, Verhoeven, van Leeuwe and van Balkom, 2008). In this study, these problems also predicted language abilities of the LI children. Phonological memory was found to predict phonological abilities (which in turn predicted syntactic abilities); central executive memory predicted lexical-semantic abilities; and visual memory predicted speech production abilities (Van Daal et al., 2008). In sum, when examining the working memory model of Baddely, the focus typically is on SLI children's verbal working memory (i.e. phonological loop). However, non-verbal working memory, (i.e. visuospatial sketchpad) is also affected in children with SLI.

Other studies, not specifically directed at the Baddely model, but aiming at non-verbal working memory capacity in SLI children also report problems. Marton (2008) showed that children with SLI (5- and 6-year-olds) perform more poorly than their age-matched peers on several visuospatial working memory tasks. Older SLI children (7- to 12-year-olds) also have problems in this domain (Im-Bolter et al., 2006; Lucács, Kas, Kemény and Krajcsi, 2010; Henry, Messer and Nash, 2012). In general, when problems with non-verbal working memory are reported, they seem to be associated more closely with language impairment than with ADHD (Cohen et al., 2000; also see Im-Bolter and Cohen, 2007). Only a few studies fail to find non-verbal working memory problems in children with SLI (Bavin, Wilson, Maruff and Sleeman, 2005; Archibald and Gathercole, 2006; Archibald and Joanisse, 2009 – age range 4-11 years of age).

Although the focus in the SLI literature is on models of working memory, research focusing specifically on non-verbal inhibition, planning, cognitive flexibility and fluency has also been conducted.
However, research in these areas, relative to working memory research, is sparse.

Im-Bolter, Johnston and Pascual-Leone (2006) found, among other things, that children with SLI (7-12 years of age) exhibit poor inhibitory control. Deficits in inhibition were also found by Henry, et al. (2012; mean age: 11.5 years) and by Lukács, et al. (2010; mean age: 10.5 years). Bishop and Frazier Norbury (2005) compared several measures of inhibition in four groups of children: children with high functioning autism, children with pragmatic language impairment, children with typical SLI and typically developing children (6-10 years of age). They found inhibitory problems for all three clinical groups.

According to Kahmi, Ward and Mills (1995), planning is not affected in children with SLI (5-7 years of age). However, this study only included a small number of children, and it did not use traditional planning tasks. Marton (2008) compared SLI children to typically developing children (8-11 years of age), and her results did point at some planning problems, although not unequivocally so. Weyandt and Willis (1994) did find that children with LI performed worse on a planning task than typically developing children (6-12 years of age). Interestingly, the scores of the LI children in this study did not differ significantly from the children with ADHD, which were also included in the study. The study by Henry, et al (2012) also pointed out that SLI children (mean age: 11.5 years) had lower planning scores than typically developing children. These SLI children performed at comparable level as a group of children with general low functioning.

The results with respect to cognitive flexibility are not consistent either. Williams, Stott, Goodyer and Sahakian (2000) found significant effects of hyperactivity, but not of specific language impairment on cognitive flexibility in 6-year-old children. Studies by Dibbets, Bakker and Jolles (2006), Henry, et al. (2012), Im-Bolter, Johnston and Pascual-Leone (2006), Kiernan, Snow, Swisher and
Vance (1997), and Weyandt and Willis (1994) did also not find difficulties with cognitive flexibility in (S)LI children (age range 4-12 years of age). On the other hand, Lukács, et al. (2010) did find problems with cognitive flexibility in the LI children (8-12 years of age) in their study. Moreover, Marton (2008) also found that cognitive flexibility was impaired in children with SLI (8-11 years of age).

Bishop and Frazier Norbury (2005) compared measures of verbal fluency in several groups of children (6-10 years of age). Verbal fluency was not impaired in SLI. Dunn, Gomes and Sebastian (1996) also did not find verbal fluency problems in SLI children compared to typically developing children (4-9 years of age). On the other hand, in a case study of an 11-year-old SLI child, verbal fluency was weak, although non-verbal fluency was normal (Koponen, Aro and Ahonen, 2009). There is only limited evidence available with respect to non-verbal fluency. Weyandt and Willis (1994) did not find non-verbal fluency problems in 6- to 12-year-old LI children. However, the study by Henry, et al. (2012) did find difficulties with non-verbal fluency in SLI children (mean age 11.5 years). This study by Henry, et al., mentioned several times in this section, is important. It is well designed, included a large number of children and measures, and controlled for age and non-verbal IQ.

In sum, there is evidence that children with SLI experience problems in non-verbal executive functioning. Problems with inhibition were found in all studies. However, studies reporting on working memory, planning, cognitive flexibility and fluency were less consistent; sometimes problems were reported, and sometimes problems were not reported.

It is difficult to draw firm conclusions since, compared to ADHD, relatively few studies about executive functioning in SLI are available. Thus, a comparison of the findings of the reviews in Section 3.2.1
and in Section 3.2.2 is difficult. Moreover, it is unclear how specific the executive functioning deficits in SLI are, and whether or not profile and level differences can be distinguished. The so-called ‘discriminant validity problem’, described by Pennington and Ozonoff (1996) is applicable to SLI as well as to ADHD.

Table 3-1 gives an overview of the affected executive functioning domains in children with ADHD and in children with SLI.

<table>
<thead>
<tr>
<th>Non-verbal executive function</th>
<th>ADHD</th>
<th>SLI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inhibition</td>
<td>++</td>
<td>(+)</td>
</tr>
<tr>
<td>Working memory</td>
<td>+/-</td>
<td>(+/-)</td>
</tr>
<tr>
<td>Planning</td>
<td>+/-</td>
<td>(+/-)</td>
</tr>
<tr>
<td>Cognitive flexibility</td>
<td>+/-</td>
<td>(+/-)</td>
</tr>
<tr>
<td>Non-verbal fluency</td>
<td>+/-</td>
<td>(+/-)</td>
</tr>
</tbody>
</table>

Table 3-1: affected non-verbal executive functioning domains in ADHD and SLI. ++ = salient problems; + = problems; +/- = problems possible; - = no problems. The brackets point at the limited availability of research, which makes it difficult to draw firm conclusions.

Table 3-1 shows that ADHD children exhibit problems in inhibition, as do SLI children. The other executive functions are unclear. Both ADHD and SLI children may or may not encounter problems in working memory, planning, cognitive flexibility and fluency. So far, a direct comparison between ADHD and SLI children’s performance on the five executive functions has not been conducted.

In this thesis, we will compare non-verbal executive functioning of children with ADHD, children with SLI and typically developing children. This is formulated in the second of the three research questions in this study:

Do children with ADHD differ in executive functioning in comparison with typically developing children and do they differ from SLI children?
The focus in this study will be on the five major executive functions, all tested non-verbally, that is inhibition, working memory, planning, cognitive flexibility and fluency (Pennington and Ozonoff, 1996).

3.3 **Executive functioning in relation to language**

The proposal of Tannock and Schachar (1996) that executive dysfunctioning may account for both the core behavioral problems and the pragmatic disorders commonly observed in ADHD, was briefly mentioned at the start of this chapter and will now be discussed in more detail.

Tannock and Schachar (1996) put forward several arguments to arrive at their proposal. First of all, they argue, on the basis of their literature review, that deficits in executive functioning are fundamental to ADHD and account for the core behavioral symptoms of the disorder. These deficits might be due to delayed frontal lobe maturation, possibly of genetic origin. Their second argument is that the prefrontal regions of the cortex are not only involved in the temporal organization of behavior, but also in the production and interpretation of language. More specifically, frontal lobe lesions disturb the regulatory function of speech; adults with frontal lobe lesions can no longer control their behavior with the aid of their own (inner) speech. Thirdly, their review of the types of communication disorders associated with ADHD reveals the strongest link to be between ADHD and problems in the expressive language domain, in particular in pragmatics. Pragmatic problems, placing heavy demands on for example planning, organization and monitoring, would indeed be predicted to occur in case of executive dysfunction. Finally, they argue that if executive dysfunctioning indeed underlies behavioral and pragmatic language problems in ADHD, treatment aimed at executive dysfunctioning should alleviate both kinds of problems. This indeed seems to be the case. For
example, ADHD stimulant medication is ameliorating overt behavioral symptoms, but there is also evidence that it ameliorates pragmatic symptoms.

It is important to realize that Tannock and Schachar (1996) relate problems in the basic language systems to reading disorders, and not to ADHD. In other words, Tannock and Schachar do not predict that phonology, morphology/syntax and semantics are related to executive functioning. Their proposal specifically focuses on pragmatic aspects of language.

Tannock and Schachar (1996) suggest a strong relation between EF and language. In this thesis this relationship will be explored in the third of the three research questions:

Is there an association between executive functioning and language measures in children with ADHD, children with SLI and typically developing children?

### 3.4 Overview research questions and general expectations

Section 2.1.2 and Section 2.2.2 discussed language in children with SLI and ADHD. It was found that SLI children encounter problems in all language domains, albeit to varying degrees. The problems in productive grammar are most noticeable. In the case of ADHD however, the picture is less clear, although there is strong evidence

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15 The study by Van Lambalgen, Van Kruistum and Parigger (2008), discussed in Section 2.2.2, and preceding the study in the current thesis, aimed to shed more light on the relation between executive functioning, in particular planning, and language in Dutch ADHD children (7-9 years-old). However, in this study, problems with executive functioning were only hypothesized, and not tested empirically. Moreover, this study did not control for co-morbid reading disorders. So, it could be that the group difference that was found, not in pragmatics, which was not investigated in the study, but in one of the basic language systems, namely (morpho-)syntax, was due to high scores in those ADHD children who also exhibited reading problems.
that children with ADHD experience pragmatic language production problems. Section 3.2.1 and Section 3.2.2 on non-verbal executive functioning showed that ADHD children exhibit salient problems in inhibition, and that SLI children have noticeable problems in inhibition as well. However, it also became clear that we need to know more about the other four executive functions. Findings for working memory, planning, cognitive flexibility and fluency were inconsistent and/or too little evidence was available to warrant any firm conclusions.

The first two research questions are a consequence of these findings, and aim to shed more light on ADHD and SLI children’s language (pragmatics and grammar) and their executive functioning (non-verbal inhibition, working memory, planning, cognitive flexibility, fluency):

1. *Do children with ADHD differ in language production in comparison with typically developing children and do they differ from SLI children (see Section 2.4)?*

2. *Do children with ADHD differ in executive functioning in comparison with typically developing children and do they differ from SLI children (see Section 3.2.2)?*

In general, the literature suggests that SLI children will primarily have language problems and that ADHD children will primarily have executive functioning problems. However, this might not be the case for pragmatic problems on the one hand (see Table 2-3) and inhibitory problems on the other hand (see Table 3-1). That is, these problems might be experienced by both the SLI and the ADHD groups.
The third research question aims to test the executive functioning theory of Tannock and Schachar (1996), which was discussed more extensively in Section 3.3:

3. Is there an association between executive functioning and language measures in children with ADHD, children with SLI and typically developing children (see Section 3.3)?

Tannock and Schachar’s (1996) model suggests that pragmatic language measures will correlate with measures of executive functioning. They do not mention a specific executive function, but from the literature review it is possible that inhibition will show the highest correlation with pragmatic language measures. Correlations between measures of grammar and executive functions are not predicted by the model.