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Language and executive functions in Swedish preschoolers

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Abstract

The main goals of this dissertation are to investigate the associations between language and executive functions, including selective auditory attention, in Swedish children aged 4–6, to examine possible links to factors relating to the child and his/her social environment, and to evaluate preschool interventions with regard to potential improvements in language and/or executive functions. Measures were obtained by combining results from behavioral tests, language samples in the form of narratives, parent and teacher ratings and a measure of selective auditory attention as brain activity. Additionally, previous work regarding the nature and direction of the association between language and executive functions is reviewed and discussed. Progress during preschool years in language and executive functioning development seem to go hand in hand, and a body of work has indicated that language and executive functions are closely associated, although directions of potential casual relationships are still unclear. For Swedish, preschool-aged children, little is known of the language–executive functions relationship and the extent to which these skills can be improved via pedagogical working methods or interventions. The first paper investigates the language–executive functions relationship and potential associations to background factors, and the second paper examines the same research questions in larger sample, adding a selective auditory attention measure. The third paper constitutes one of the first randomized controlled trials in the Swedish preschool context and investigates effects of two contrasting pedagogical interventions compared to business-as-usual. The fourth paper explores links between children's spontaneous explanations of a fictional misunderstanding, their language skills and their executive functions. In line with previous work from other contexts, results confirm an association between children's grammar skills and inhibition, including selective auditory attention. Children's socioeconomic background is significantly related to language skills, executive functions and selective attention. The current results also suggest a female advantage for receptive vocabulary and morphosyntax and indicate that bi- and multilingual children perform lower than monolingual peers with regard to receptive vocabulary in the majority language, also when controlling for socioeconomic status. The preschool interventions did not lead to any gains in language, executive functions or selective attention compared to the control group. Further work is clearly needed to provide a solid evidence-base for Swedish preschool practices. Future studies should focus on identifying relevant mechanisms in order to enable early intervention targeting children at risk for lagging behind their peers already in preschool. Previous empirical work as well as theoretical suggestions regarding the nature and direction of the links between language and executive functions are divergent, which is related to a lack of consensus with regard to underlying theories and to problems with definitions and assessment. In this thesis, it is suggested that the association is intertwined and reciprocal, congruent with a view on development as dynamic and complex and in line with a theory of mutualism. Future work is needed to refine theories and to formulate testable hypotheses regarding the language–executive functions relationship.

Keywords: *language development, narrative, executive functions, theory of mind, preschool, event-related potentials, selective attention, Swedish, early childhood.*

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Till morfar Rolf

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April 2021, Stockholm

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List of papers

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IV. Tonér, S. (submitted manuscript). Conveying a fictional false belief in narrative.

Contents

1. Introduction

Language is an unsurpassed tool for communicating, thinking and learning. By the time children start school, they have learned to master a wide array of linguistic devices, such as building complex sentences, using increasingly complex and abstract vocabulary, refining their phonological system and beginning to be able to separate language form and language content (metalinguistic awareness). Additionally, by the age children start school, they have vastly improved their ability to use language in discourse, for example to construct increasingly sophisticated narratives, which also includes the ability to switch perspective and understand the needs of the listener. During the same time in which language skills undergo rapid development, children's self-regulatory skills, or executive functions (EF) improve substantially. Progress within these two cognitive domains seems to go hand in hand and a body of work indicates that language and EF development are closely associated in various ways during early childhood, although directions of any causal relationships are still unclear.

In this thesis, I attempt to shed further light on relationships between aspects of language skills and EF in Swedish, typically-developing children aged 4 to 6. I will do so by presenting and elaborating on four empirical studies: Study I is a pilot study, in which an assessment battery of language and executive functions was assembled and preliminary investigations conducted regarding associations between language and EF in relation to age, sex and socioeconomic status in a group of 47 children. Study II expands on Study I by continuing to examine the associations between language and EF in 431 children, adding data acquired from an event-related potential (ERP) electroencephalography (EEG) experimental paradigm measuring selective auditory attention for a subsample of 138 children. In Study III, the same 431 participants were randomized to two preschool interventions or control group. The interventions were designed as refined and scripted versions of existing preschool pedagogical working methods and were evaluated with regard to eventual effects on children's language, executive functions, communication, early mathematic skills and socio-emotional skills. The intervention study was conducted as a team effort with scholars from a range of fields, including preschool pedagogics, psychology and linguistics and is one of the first randomized controlled trials in the Swedish preschool context. Finally, Study IV involves a subsample of 141 participants from Studies II and III and focuses on the relation between levels of explicitness in relating a fictional false belief, language and EF skills as well as possible connections to background factors.

The thesis is structured as follows: In chapter 1 below, I introduce the core concepts that this thesis is concerned with; that is language, executive functions and selective auditory attention. In chapter 2, I provide the overarching perspective on development adopted in the current work as well as an overview of language and EF development. Some influential models and theories of language and EF, the potential relationships between these two aspects of human cognition, and challenges relating to the lack of consensus are discussed in chapter 3, and chapter 4 includes an account of the assessment of language, EF and selective attention, including a summary of all assessments and tasks used in the current studies. A summary of the Swedish preschool system and Swedish preschool research, including the lack of evidence-base for current pedagogical practices, is provided in chapter 5. In chapter 6, an overview of the four studies and their contributions to the field is provided, and results and implications thereof, including future directions, are discussed in chapter 7.

1.1. Core concepts and research questions

In the next section, central concepts will be described and brief introductions of the topics which are the foci of this thesis will be provided. Finally, overarching research questions are presented.

1.1.1 Language

Language is a system of conventionalized spoken, signed or written symbols by which we communicate with one another and express our identity and emotions. The language system is hierarchical, encompassing subsystems of phonology, morphology, syntax, semantics and pragmatics. Moreover, human language is characterized by *productivity*, that is, that speakers can recombine forms they already know to produce an utterance they have never heard before, *semanticity* – it represents ideas and objects symbolically – and *displacement*, in other words, the possibility to talk about things outside the immediate context (e.g. Brown, 1973).

Language acquisition and use are affected by complex interaction of linguistic as well as social, cognitive and cultural influences (e.g. Adams, 2002) and language development continues throughout our lives. Individual differences in language acquisition and processing are evident across all components of the linguistic system and across the entire population, not only during childhood, and result from a complex interplay of cognitive systems and the environment (e.g. Kidd, Donnelly, & Christiansen, 2018). Evidence points toward some discontinuity of language skills from infancy to early childhood (e.g. Duff, Reen, Plunkett, & Nation, 2015; McKean et al., 2015; Rescorla, 2011). A review by Rescorla (2011) showed that children who only had expressive language problems at 18-35 months, so-called late talkers, mostly caught up with peers, whereas most children with language difficulties at age 5 were not late talkers. If on the other hand young children have receptive language problems, they are at risk of continuing language difficulties/language disorder, as well as being at risk for later learning, behavioral and emotional problems (ibid.). Genetic factors play a part both in the rate of language acquisition and in the level of adult linguistic proficiency. A meta-analysis of genetic studies of language concluded that genetic factors account for a large proportion of language variance in people with language disorders and they account for some of the variance in the general population (Stromswold, 2001).

Different aspects of language skills (an often-used measure is vocabulary size) have predictive value for a wide range of outcomes, such as literacy (e.g. Duff et al., 2015; Lee, 2011) and mathematical ability (e.g. Moll, Snowling, Göbel, & Hulme, 2015). Language ability is also a strong predictor of IQ, including non-verbal IQ (e.g. Bogičević, Verhoeven, & van Baar, 2019; Cejas, Mitchell, Hoffman, & Quittner, 2018; Marchman et al., 2018; Peyre, Charkaluk, Forhan, Heude, & Ramus 2017).

From an international perspective, interventions targeting language, aiming at all children, not only children with language disorders or those at risk for language difficulties, seem to be less common than universal programs aiming at improving EF and behavior. Work by McKean and colleagues (2015) has shown that up to the age of 4, individual differences in language abilities are to a large extent explained by factors which cannot be targeted in interventions or training programs, such as gender or a family history of language difficulties. Between 4 and 7 years of age, a large part of variability in language growth is explained by factors that can be modified through interventions with the child and family (ibid.). There is less support for the efficiency of language interventions compared to EF, but there is evidence that typical preschool instruction does not always close the gap between children at different levels of linguistic ability (Greenwood et al., 2013). Swedish preschool adheres to the national preschool curriculum, which includes aspects of language development, but does not contain methods or programs to target specific cognitive skills (Skolverket, 2018a).

When assessing language or collecting language data for research purposes, a combination of methods is usually employed, describing the child's skills within different linguistic domains such as vocabulary, morphosyntax or discourse-level skills by using formal instruments, observations, language sampling, checklists and parental questionnaires (see also Section 4.2 below). Additionally, in research, experimental methods can be used to assess aspects of language processing that are hard to capture behaviorally. The studies included in this thesis investigate language skills and potential effects on language skills by preschool intervention in mainly typically-developing children by combining language tests, language sampling in the form of collecting children's narratives, and parental questionnaires.

1.1.2 Executive functions

Executive functions (EF) are cognitive control processes that regulate thought and action and are considered to be among the most heritable psychological traits (Friedman, Miyake, Young, DeFries, Corley, & Hewitt, 2008). EF can also be referred to as cognitive control, effortful control, executive control or executive attention, sometimes separating the behavioral manifestations of EF (the ability to self-regulate) from the cognitive and/or neural processes underlying these skills (executive control, executive attention etc.). For simplicity, I choose to refer to this set of functions, skills or networks as EFs. EFs refer to an array of top-down neurocognitive processes involved in goal-directed behavior used to solve problems, shift tasks, plan ahead and implement goals, as well as the concept of self-control. Although there is no universally agreed-upon definition of EF and a lack of conceptual clarity (see also Klenberg, Korkman, & Lahti-Nuuttila, 2001 and section 3.2 below), most seem to agree that three core EF components form the basis for more advanced aspects of cognitive control. [1] These components are shifting/cognitive flexibility (sometimes referred to as attentional flexibility, see e.g. Carlson, 2005, and Carlson, Faja & Beck, 2016), inhibitory control and working memory (e.g. Diamond, 2013; Miyake & Friedman 2012, Miyake, Friedman, Emerson, Witzki, & Howerter, 2000).

These components are correlated but separable from a behavioral genetic perspective, at least in adults (e.g. Friedman et al., 2008). Cognitive flexibility builds on the other two core EF components and entails changing perspectives spatially or interpersonally and to think outside the box (Diamond, 2013; Garon, Bryson, & Smith, 2008). Inhibitory control, sometimes referred to as behavioral inhibition, can be described as consisting of three interrelated processes: first, inhibiting an initial, prepotent response to an event or stimulus,

[1] It may be the case that the three so-called core EF components have simply been more examined than other potential aspects of EF and therefore perceived as more central (Friedman et al., 2008).

second, to stop an ongoing response, and third, to prevent interference due to competition of other stimuli (e.g. Barkley, 1997a; van Velzen, Vriend, de Wit, & van den Heuvel, 2014). Working memory entails working with information which is no longer perceptually present (e.g. Diamond, 2013). Not all scholars distinguish clearly between working memory (maintenance and manipulation) and short-term memory (only maintenance; see also Aben, Stapen, and Blokland (2012) for a discussion). Another area of disagreement among EF researchers is whether inhibition is a separate cognitive skill from working memory or if it is a product of exercising working memory (Diamond, 2013).

EF abilities undergo rapid development during early childhood (e.g. Blair & Raver, 2015; Moffit et al., 2011) and it is claimed that strong EF ability can act as a resilience factor. Resilience is commonly defined as protective processes that reduce maladaptive outcomes under conditions of risk, and Masten (2014) noted that the ability to regulate one's emotions and arousal to initiate problem solving and gather more information about the event are among the most important resilience factors. Individual differences in EF have furthermore been consistently linked with individual differences in intelligence and there seems to be a strong genetic overlap between EF and intelligence (e.g. Engelhardt et al., 2016) as well as some conceptual overlap. It has been suggested that all tests of cognitive ability taps into EF, but intelligence and EF are nevertheless dissociable (e.g. Crinella & Yu, 1999).

In spite of a large number of varying definitions and theories of EF (see also Section 3.2 below) and some disagreement with regard to how the different components are measured and whether the components can be separated in young children, results on EF tasks still have large predictive value for a number of important outcomes. Early EFs predict lifelong achievement, health, wealth and quality of life (e.g. Diamond, 2013) and could be more important for academic achievement than traditional measures of intelligence (Zelazo, 2015).

EF abilities are trainable through repeated practice, by many different approaches and there is an array of interventions of various kinds that have been shown to have an effect on EF. Several interventions that improve EF have in common that the children with the initially poorest ability gain the most, which means that early EF intervention has the potential to reduce achievement gaps (e.g. Diamond, 2013). There are some preschool curricula and programs with documented effects on EF: Tools of the Mind and Montessori curricula, Promoting Alternative Thinking Strategies (PATHS) and the Chicago School Readiness Project have been shown to improve EFs, importantly also when children are randomly assigned to the program (Diamond & Lee; 2011; Diamond & Ling, 2016; see also Section 5.2.3 below). However, randomized controlled trials on interventions targeting EF are few and larger meta-analyses are needed for a solid evidence-base (Baron, Evangelou, Malmberg, & Melendez-Torres, 2017).

A systematic review and meta-analysis of 63 studies evaluating effects of interventions based on socioemotional learning on preschooler outcomes concluded that social and emotional learning programs seem to be an effective way to increase, among other things, behavioral self-regulation in children aged 2 to 6 (Blewitt et al., 2018). From the Swedish perspective, computerized training targeting working memory and inhibition has been evaluated on typically developing children aged 4–5 and the training was conducted on-site in preschools (e.g. Thorell, Lindqvist, Bergman-Nutley, Bohlin, & Klingberg, 2009), but studies examining possible impact on EF by more general pedagogical working methods, programs or curricula have to my knowledge not previously been conducted in the Swedish context.

To assess EF, an array of behavioral and experimental tests and tasks are available, as well as questionnaires and checklists. Challenges in EF assessment include that the same task may be described as assessing different aspects of EF, depending on the definition and theory of EF one favors. The studies included in this thesis investigated EF and potential effects on EF by preschool intervention in mainly typically-developing children by combining behavioral tests and parental and teacher questionnaires. Event-related potentials were used to measure the specific EF aspect of selective auditory attention, see below.

1.1.3 Selective auditory attention

Attention as an over-arching concept is often described as consisting of three general functions: alerting, orienting and executive attention (e.g. Petersen & Posner, 2012). The latter overlaps with the EF construct, also in terms of neural processing, and measures of executive attention are also considered measures of EF. However, selective auditory attention may be connected to the orienting network, since this network deals with the ability to prioritize sensory input. I will consider selective auditory attention as an integrated part of EF, but for practical reasons, selective auditory attention will often be reported separately, since in the current data set, attention is assessed with ERP, whereas other aspects of EF are measured with behavioral tasks, and parent and teacher ratings.

> What we see, hear, feel and remember depends not only on the information entering our senses, but also upon which aspects of this we choose to attend. (Driver, 2001, p. 53).

Put simply, selective auditory attention is the ability to focus on some auditory input while at the same time ignoring some other auditory input. Selective attention, regardless of modality, can be regarded as a part of, or a prerequisite for shifting/cognitive flexibility (see e.g. Dajani & Uddin, 2015; Diamond, 2013), or as one aspect of inhibitory control, that is, interference suppression (see e.g. Brydges, Fox, Reid, & Anderson, 2014; Gandolfi, Viterbori, Traverso, & Usai, 2014). It seems intuitive that selective auditory attention has potentially great importance to help us navigate and communicate in everyday situations, in which we both need to pay attention to one speaker in the presence of distractors, and also dynamically redirect attention to different speakers or other sources of auditory information.

Similar to language skills and (other aspects of) EF, interindividual variation in selective auditory attention skills exists also in typically developing, healthy samples and attentional abilities have been described as a foundational developmental skill important for academic outcomes (e.g. Neville et al., 2013).

Both behavioral and neurophysiological studies indicate that selective auditory attention develops during childhood and at least until adolescence. This development can be said to have two components: the ability to selectively attend the relevant stimuli and the ability to successfully ignore or suppress stimuli that are irrelevant. Interventions focusing on rapid auditory processing have been shown to improve selective auditory attention as measured with ERP (Stevens, Fanning, Coch, Sanders, & Neville, 2008), as well as interventions targeting early literacy (Stevens et al., 2011).
Interventions targeting self-regulation, focusing both on children and on parent-training, have also shown improvements in attention, in particular in children from lower socioeconomic backgrounds (Neville et al., 2013).

Selective auditory attention has been examined with ERP technique since the 1970s. With ERP we can measure the dynamics of processing in the brain and the technique has therefore become a vital tool for testing theories of perception, attention, and cognition (Woodman, 2010). In Study II and Study III, an ERP measure of selective auditory attention, the Swedish AudAt, was employed and related to language and to (other aspects of) EF.

1.1.4 Research questions

1. What are the associations between language and executive functions, including selective auditory attention, in Swedish children aged 4–6?
2. What are the associations between language/EF/attention and factors relating to the child and his/her social environment?
3. Can teacher-delivered preschool interventions improve language/EF/attention?

2. Development

The starting point of this chapter is a statement of the view of development generally adopted in this thesis. I continue to describe some of the similarities and differences between language and EF development before providing an overview of language and EF milestones from infancy and through early childhood. The summary should not be seen as comprehensive, but rather serves to elaborate on the literature review in the papers included in this dissertation. I proceed by highlighting potential associations between language/EF and demographic factors such as socioeconomic status or bi-/multilingualism and provide some motivation as to why results regarding language and EF development may not be completely generalizable across cultures and languages. A short section on development of mathematical ability is also included; mathematical skills were targeted in the interventions in Study III.

2.1. Development as dynamic and emergent

The development of complex cognitive processes, like language and EF, requires an understanding of interactions among a large number of components and of properties that emerge as a result of those interactions. See Figure 1 for a very schematic overview of some of the potential factors at play in language and EF development. Dynamic Systems Theory (e.g. Thelen, 2001; Smith & Thelen, 2003) has led to a revolution in the field of motor development and has for the past decade or so also extended into the domain of cognitive development (see Spencer, Perone, & Buss, 2011, for a review). A key characteristic of Dynamic Systems Theory is the rejection of classical dichotomies such as nature versus nurture and stability versus change. The central unit of study is instead *the organism in context*. A concrete example of such individual–context relational processes is that a verbally precocious child may elicit richer language input, thereby maintaining, and possibly enhancing that child's linguistic advantage (Bornstein & Putnick, 2012).

Another central idea in Dynamic Systems Theory is that behavior and development are emergent properties of system-wide interactions, able to create something new from the multitude of interacting components in the system, in other words a self-organizing system (e.g. Munakata & McClelland, 2003; Spencer, Perone, & Buss, 2011). An emergent and dynamic perspective on development also entails that the important dimension is the stability of behavior in its particular context over time, rather than whether or not a child 'has' an ability (Smith & Thelen, 2003). Any distinction between competence, that is, some sort of idealized capacity, and performance in the form of observable behaviors, is not meaningful.

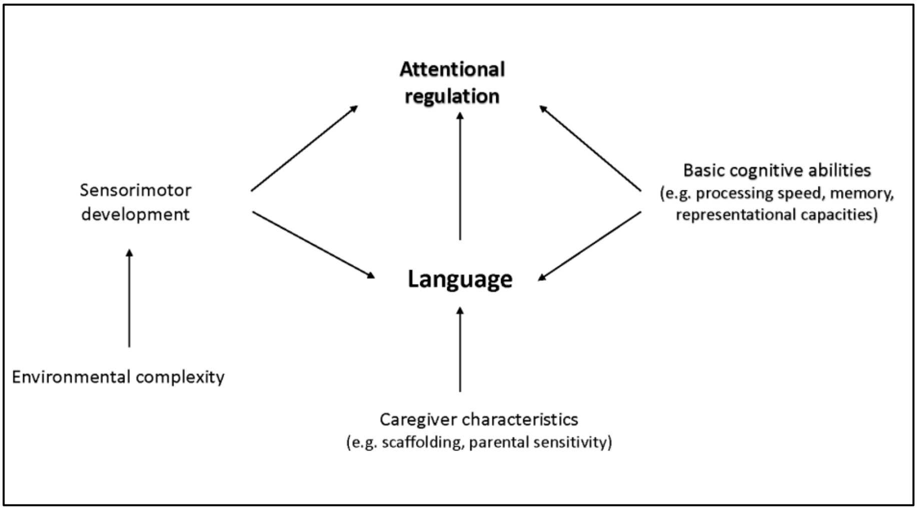

Figure 1. Early language and EF development, here referred to as attentional regulation, depends on multiple interactions (adapted with permission from Thompson & Steinbeis, 2020).

2.1.1. Critical periods

Critical, sensitive, or optimal periods for development have been observed in various developmental systems in humans as well as other species, and are suggested to be necessary to establish an optimal neural representation of the environment to guide future action. These periods may be constrained by the maturation of the neural system and triggered by the input (e.g. Werker & Hensch, 2015). Kievit (2020) suggested that during sensitive periods, small individual differences may have especially pronounced, long-lasting consequences for cognitive development.

Exposure to language during a certain time span seems crucial to tune the developing system to the ambient language, and the critical period for syntax has been argued to end as early as around age 1 (e.g. Friedmann & Rusou, 2015). For EF, the potential role of sensitive periods has been less clear, but in parallel with language, cognitive deprivation leads to EF deficits, distinct to other types of adverse conditions such as maltreatment. Similar to language, it seems as if early severe deprivation has long lasting effects for later EF (see Thompson & Steinbeis, 2020, for a summary).

2.1.2. Shared intentionality and Theory of Mind

> An individual has a theory of mind if he imputes mental states to himself and others. (Premack & Woodruff, 1978)

Aspects of shared intentionality, mentalizing, or Theory of Mind seem to be of importance both for language and EF development (see Devine & Hughes, 2014; Milligan, Astington, & Dack, 2007 for meta-analyses). To read the intentions of others and to use a variety of cues in different modalities are considered vital parts in early language and communication development, but also in development of cognitive control/EF. This important milestone is made possible by joint attention skills, emerging from the age of 9 months, when the child exercises intentional control in increasingly longer periods of sustained attention (e.g. Ibbotson, 2020; Tomasello, 2018; Tomasello & Rakoczy, 2003). Available evidence suggests that infants begin with local understandings of goal-directed actions that become broader during the first year of life and by 14–18 months, children are able to use behavioral evidence of communication partners' intentional states to interpret their subsequent actions as well as their utterances and emotional expressions (see Woodward, 2005, for a review). The ability to understand the intentions of others has also been framed as intersubjectivity (e.g. Airenti, 2015; Trevarthen, 1998). Since the seminal work by Premack and Woodruff (1978) it has been shown that chimpanzees (and also other primates and possibly some bird species) understand the goals, intentions, perception and knowledge of others. It has however been argued that the ability to understand false belief is only found in humans (see Call & Tomasello, 2008, for a summary).

Similar to language and EF development (see Sections 2.2 and 2.3 below), advanced aspects of shared intentionality develop substantially in early childhood, and false belief understanding seems to change in a quite sudden fashion at around 4 years of age (e.g. Happé, 1995; Wimmer & Perner, 1983). These more sophisticated features of shared intentionality are not just a process within the individual. Rather, Tomasello (2018) proposes that the child coordinates his/her own perspective with the perspective of the social partners in the context of human-unique forms of communication. To possess a Theory of Mind is thus closely connected to language; it is strongly predicted by language, or may be considered an aspect of pragmatic ability. Hale and Tager-Flusberg (2003) showed that language training improved Theory of Mind, but not vice versa. Happé (1995) showed that receptive vocabulary predicted false belief performance in both typically-developing children and children with autism. However, the latter group seemed to require stronger vocabulary skills than typically-developing peers in order to pass Theory of Mind tasks (ibid.). Milligan, Astington and Dack (2007) examined data from over 100 studies and found that there were stronger effects from earlier language to later false belief abilities than the reverse; effect sizes were overall moderate to large. Performance on Theory of Mind tests may however predict the ability to understand figurative language and to understand the intentions of communication partners (e.g. Happé, 1993), but results are not consistent and Theory of Mind may be necessary but not sufficient to interpret figurative language such as metaphors. For instance, Norbury (2005) showed that semantic skills better predicted comprehension of metaphors than Theory of Mind skills.

In the process of coordinating different perspectives, it has been suggested that the child also recruits EF, for instance, using cognitive flexibility skills to shift perspectives, or keeping items in working memory while coordinating them in some way (e.g. Tomasello, 2018). In a large meta-analysis, Devine and Hughes (2014) found moderate associations between EF and false belief understanding and showed that early EF predicted later variation in false belief understanding but not vice versa.

2.1.3. Protracted development

Traditionally, language acquisition is conceptualized as taking place from early infancy (starting already *in utero*) and being more or less finished in early childhood, a view in part reflecting a theoretical perspective of language in which syntax is the main topic of interest. EF development on the other hand, including auditory selective attention is seen as protracted and lasting into adulthood. However, when taking discourse-level language skills into account, language continues to develop also qualitatively into adolescence and adulthood, see also Section 2.2.3 below.

2.1.4. "Everybody knows what language is"

EFs are less tangible than language and the concept of EF cannot be considered general knowledge. This difference reflects that EF represent a latent construct, and the structure of EF seems to vary depending on when in development EF is assessed (see also chapter 3). It is true that there is no universally accepted theory of language, but at least on a superficial level, people in general have some more or less clear idea of what 'language' is, can provide some kind of layperson's definition and examples of linguistic aspects.

Most parents and professionals working with young children in Sweden can name some relevant milestones in language development, for instance that we expect a child to utter his/her first word around the time of their first birthday and that a 2–year-old usually combines 2–3 words into short phrases. The development of cognitive control on the other hand is not discussed in everyday contexts to the same extent as aspects of language development. Behaviors and abilities related to typically-developing inhibition, working memory or cognitive flexibility are seldom referred to as EFs in professional contexts such as the preschool or child health services. The Swedish preschool curriculum lists a number of language and communication aspects, including that every child in a Swedish preschool should be given the opportunities to develop a nuanced vocabulary and the ability to ask questions, tell stories, and communicate with others in various contexts, whereas there are no specific mentions of the development of EF or behaviors and skills that clearly would categorize as EFs (Skolverket, 2018a). The checklists used in the Swedish child health services do not include any aspect of EF, except at 5 years of age, when there is one question regarding whether the child can wait for his/her turn for instance during floor time at preschool; this ability is framed as representing concentration/cognitive development. In contrast, at every age, checklists include an array of questions regarding language and communication development (Reuter, 2018). This difference may reflect a view in which language and communication is seen as a learned social behavior, malleable by aspects of the environment, whereas EFs are perhaps more seen as reflecting underlying traits such as personality or temperament, rather than skills that are amenable to improvement.

2.2. Language development

> Language development is the result of complex interactions between the child's biological make-up, their family, school and community and the social and cultural context. (McKean et al., 2015, p. 3)

The comprehension and production of conventional symbols used to direct the attentional and mental states of other persons as well as of one-self can be considered the essence of language acquisition. Human language does not only allow us to share needs and desires, but also to comment on the past and the future, to consider new and never-experienced possibilities and to construct poetry and narrative (see also Werker & Hensch, 2015).

Language development have historically been studied from two separate perspectives: one which focuses on language development as the product of mental processes—an approach which has been common from a linguistic point of view, not least amongst generativist scholars (see also Section 3.1 below). The second perspective focuses more on the shaping role of children's social contexts on language acquisition and has been more common in the study of social and cognitive development (see also Hoff, 2006). If these two approaches are combined, the question that arises is: How do the internal mechanisms for language acquisition and the external environment interact? In the last couple of decades, an increasing body of research has combined these two approaches to get a fuller picture of child language development.

Children acquire language under a diversity of conditions, and given the functional significance of human language, it seems likely that language development is influenced by complex causal mechanisms, including gene-environment interactions (e.g. Dale, Tosto, Hayiou-Thomas, & Plomin, 2015; Rogers, Nulty, Betancourt, & DeThorne, 2015). Additionally, at least some aspects of language development vary cross-linguistically and thus seem to be language- (or potentially culture-) dependent, warranting studies on different languages in various cultural contexts. The variation can be conceived of as both qualitative, with regard to linguistic structures, and quantitative in the challenges for the language-learning child. For instance, Bleses, Basbøll, and Vach (2011) showed that even in closely-related languages such as Swedish, Norwegian, Icelandic and Danish, the acquisition of past-tense inflections varies significantly with differences lasting up to young school age.

Accounts of the course of development for children acquiring Swedish as a first language are usually based on case studies or rather small corpora, often focusing on aspects of grammar as a result of mental processes (e.g. Josefsson, 2002; Josefsson, Platzack, & Håkansson, 2003), entailing that information about the children's social context is often scarce. Most work has been descriptive and data collection has thus not been aimed at eliciting specific structures or testing hypotheses (Håkansson, 2003). Large-scale studies include research on parental ratings of children's language such as the Swedish version of the McArthur Bates Communicative Development Inventories (e.g. Eriksson, 2017, see also Section 4.2.2) and work on narrative (e.g. Lindgren, 2018) and vocabulary (e.g. Öberg, 2020) in preschool-aged children.

The current description includes development in the lexical, morphosyntactic, and pragmatic and discourse-level domains, whereas speech perception and phonology are largely excluded.

2.2.1. Underlying structure of language

Children do not necessarily divide the subject of acquiring language into the same domains as linguists do. Dividing language into separate domains can to some extent be viewed as a consequence of a view in which language is divided into 1) a set of rules, or syntax and 2) a "dictionary" of idiosyncratic forms. From a cognitive linguistics perspective, it is rather argued that there are no clear-cut boundaries between what we refer to as lexicon, morphology and syntax but instead a syntax–lexicon continuum is suggested (e.g. Broccias, 2012). During development, there is evidence of critical/sensitive/optimal periods for aspects of speech perception, which in turn predicts vocabulary growth and general language proficiency. The relationship may be mediated by phonological processes (see Werker & Hensch, 2015, for a summary), further indicating the interrelatedness of different facets of language.

Relatively few studies have investigated the extent to which the theorized dimensions of language represent latent abilities at a given point in development (see also Pentimonti, O'Connell, Justice, & Cain, 2015), but existing evidence points to the possibility of a common underlying general language factor, explaining variance in both vocabulary, grammar and discourse in young children, see below. A division into sub-domains can thus be considered an over-simplification that may not be empirically supported. The studies in this thesis do not shed further light on the dimensionality of language, however, in Study III, a composite measure for language, consisting of several submeasures, was used, which is in part justified by research pointing toward a unitary language factor in early childhood (this is possibly the case also for EF, see Section 2.3.1).

2.2.1.1. A unidimensional latent structure for language?

There is some (but not unequivocal) evidence for a unidimensional model of language in early childhood (e.g. Bornstein & Putnick, 2012; Klem, Gustafsson, & Hagtvet, 2015), possibly gradually developing toward a two-dimensional model, with grammar and vocabulary loading onto different factors (e.g. Tomblin & Zhang, 2006), or a three-dimensional structure with discourse as a separate factor (Pentimonti et al., 2015).

Tomblin and Zhang (2006) investigated measures of vocabulary and grammar in school-aged children and suggested that there may be a gradual development from a unidimensional latent structure in young school age to a two-factor model in the early teens, with vocabulary and grammar loading onto different factors, and vocabulary, grammar and discourse as distinct skills by 8 years of age (ibid.). Bornstein and Putnick (2012) derived language measures from a multitude of sources, including spontaneous parent-child interaction, parental questionnaires and language tests, and found that the measures loaded on single latent variable of language at ages 20 months and 48 months. Klem, Gustafsson, and Hagtvet (2015) investigated the construct validity of a Norwegian language screening tool, including examining the dimensionality of the underlying construct in a large sample of 4–5-year-olds, and results confirmed that the screening items can be treated as a measure of a general language ability. Pentimonti and colleagues (2015) included vocabulary, grammar and discourse skills in their study on the dimensionality of language in 4–8-year old children. Although there was some ambiguity regarding the preferred model for the youngest age group, results pointed to a unidimensional model for young children. A multidimensional structure of language seems to emerge over early school years.

However, there is no complete consensus regarding the underlying structure of language. For instance, Petscher, Connor and Al Otaiba (2012) found poor model fit for a unidimensional model when investigating morphosyntax and nonword repetition in children in kindergarten and early school years. Lonigan and Milburn (2017) investigated an array of vocabulary and grammar measures in a large sample of children aged 3–12 and found support for a two-dimensional model with vocabulary and syntax as distinct factors for all age groups.

2.2.2. Milestones in language development

> Milestones in language development should represent the underlying construct of language development, including its intertwined aspects such as speech, language, and communication (Visser-Bochane, Reijneveld, Krijnen, van der Schans, & Luinge, 2020, p. 421).

Children achieve general milestones in language development in a similar order, regardless of the specific circumstances of upbringing in different cultural and linguistic contexts. However, variability in onset time and rate is substantial. The early development of language and communication is closely intertwined with (other aspects of) cognitive, social, emotional, and motor development (e.g. Leonard & Hill, 2014; Thelen, 2001; Thelen & Smith, 2003).

The use of gesture is a precursor in children's transition to language, and aspects of infants' gesture predict later linguistic abilities (e.g. Iverson & Goldin-Meadow, 2005; Nip, Green, & Marx, 2011). Around 9 months of age, the use of deictic gestures, such as pointing and giving, is associated with receptive vocabulary skills, whereas the use of gesture to label objects correlates with a later rate of expressive vocabulary acquisition. The robustness of gesture as an important communicative device is reflected in the fact that even children who are blind from birth use gesture while communicating (e.g. Iverson, Tencer, Lany, & Goldin-Meadow, 2000).

At approximately age 1, children express their first words (e.g. Ambridge & Lieven, 2011; Tomasello, 2003; Visser-Bochane et al., 2020), preceded by word learning processes, including solving the word segmentation problem– to segment words from fluent input. In a seminal paper, Saffran, Aslin, & Newport (1996) showed that infants use computational mechanisms, thereby segmenting words based on the statistical relationship between neighboring speech sounds in an artificial language. These results have been replicated with natural languages (e.g. Pelucchi, Hay, & Saffran, 2009), and statistical learning appears to be present already in newborns (see Arnon, 2019, for a summary). From age 1, children also begin to make self-repairs, in other words to clarify or modify their utterances so that they are better understood by the interlocutor (e.g. Clark, 2014).

During the second year of life, children's language abilities improve dramatically. At some point between 1 and 2 years of age, children typically shift to a faster rate of vocabulary acquisition, often referred to as the vocabulary spurt or naming explosion (e.g. Goldfield & Reznick, 1990). The expansion in productive vocabulary goes hand-in-hand with gains in receptive language abilities; at 1 to 2 years of age, children comprehend sentences with 2–3 words and they understand simple questions. Further refinement of morphosyntactic ability continues, such as the correct use of pronouns and verb forms, formulating why-questions and syntactically more complex sentences. At approximately 2 years of age, children are able to take turns and to initiate conversation, and they can also tell simple stories, usually about their everyday experiences, see also Section 2.3.3 below (e.g. Visser-Bochane et al., 2020).

During preschool years, children learn words about emotions, temporality and spatial relations (e.g. Morse & Cangelosi, 2017), and they learn to understand semantic relationships and polysemy. By the age of 4, children can infer the meaning of novel words by using semantic generalizations (Srinivasan, Al-Mughairy, Foushee, & Barner, 2017). The ability to make pragmatic inferences, such as understanding figurative language, metaphors and implicatures, has traditionally been considered to develop relatively late. More recently it has been suggested that children are able to interpret metaphors early in development, but that metaphor comprehension may be hampered by factors beyond pragmatic abilities, such as lack of sufficient world knowledge or lack of exposure to conventionalized metaphors (see e.g. Pouscoulous, 2014, for a summary).

In all studies included in this thesis, age was expected to, perhaps trivially, be significantly associated with all language measures, reflecting development and also providing some indication of the adequacy of assessment materials, many of which lack normative data for Swedish. Study I showed that age was indeed significantly and positively associated with language measures (lexical diversity, morphosyntactic accuracy, number of unified predicates). In Study II and III, age was associated with a composite measure of behaviorally assessed language and with parental ratings of language. In Study IV, age was not related to children's level of explicitness in relating a fictional false belief in the context of telling a story.

2.2.3. Narrative development

A spoken narrative can be defined as a verbal account of a past, current or future event that can be real or fictional, and fictional narratives typically show up somewhat later in development compared to stories based on real events (e.g. Adams, 2002). Storytelling is one of the most culturally significant types of discourse, and a skillful narrative does not simply consist of a linear chain of successive events. Rather, the events are packaged into hierarchical constructions, an ability which is not fully in place until adulthood (see also Berman, Slobin, & Aksu-Koç, 1994). There are additional qualitative differences in narrative organization between children and adults and also between adolescents and adults (e.g. Aksu-Koç & Tekdemir, 2004; Bamberg & Damrad-Frye, 1991), reflecting the complexity of constructing narratives and the extended development of discourse-level language use.

Narrative is a form of extended discourse relying heavily on the use of decontextualized language. A competent narrator needs knowledge about linguistic devices, cognitive skills (potentially including aspects of EF), and the ability to produce structured units of extended discourse, while considering the possibility that the listener may interpret the story differently from the narrator. A pragmatic challenge is that the narrator needs to determine how much shared knowledge can be assumed and how explicit he/she needs to be to get the message across (see also Carmiol & Sparks, 2014).

Narrative ability is, as previously mentioned, present early during development; it is usually claimed that early or minimal narratives start to appear around two years of age, in the form of two clauses joined together by a temporal marker (Labov & Waletzky, 1967) and these narratives typically concern the child's own experiences. Around age 3, children can usually retell a story aided by pictures (e.g. Visser-Bochane et al., 2020). The ability to construct narratives undergoes dramatic development between 3 and 5 years of age, which can be interpreted as a result of increasing linguistic sophistication during the preschool years (e.g. Friend & Bates, 2014; Kaderavek & Sulzby, 2000). During this period, children go from describing or listing isolated events, states and actions without using any temporal and causal markers to gradually increasing the use of such markers to connect the story and to encode relevant actions as attempts related to a plan (Trabasso & Nickels, 1992).

In the case of telling a story using picture prompts, 3–4-year-olds seem to lack abilities for building up a complete narrative which is thematically motivated at a global level, but at the same time their performance is more than just describing picture by picture and they are able to make some inferences about what is not visible on the pictures (Berman, Slobin, & Aksu-Koç, 1994). From the age of 5, most children show clear signs of temporal organization of their narratives, but variation is still vast and 5-year-olds will still mostly describe events without providing causes for those events (ibid.). At approximately 5–7 years of age, children begin to formulate goals, plans and outcomes in their narratives, reporting thematic narratives with a clear plot, thereby constructing complex hierarchical story structures (e.g. Liles, 1993; Lindgren, 2018, Trabasso & Nickels, 1992), whereas mastery of discourse markers and skilled use of anaphoric reference is usually in place at around age 7 (e.g. Karmiloff-Smith, 1985; Kyratzis & Ervin-Tripp, 1999).

There is cross-cultural variation in narrative conventions (e.g. Asplund Carlsson, Pramling Samuelsson, Soponyai, & Wen, 2001; Strömqvist & Verhoeven, 2004). Cross-cultural differences are reflected both in the content, the themes and the structure of the stories children experience, and in the narratives that children themselves create. In Sweden, children who attend preschool can be expected to participate in meaningful book reading practices, and since 2019, the curriculum for the preschool explicitly emphasizes the importance of creating opportunities for children to use, interpret, question and discuss narratives in different modalities (Skolverket, 2018a). However, it is not commonplace to explicitly practice story retell in Swedish preschool, whereas this may be the case in other cultural contexts (Asplund Carlsson et al., 2001). Rather, Swedish children are encouraged to create their own stories, based on their experiences in daily life as well as building on their encounters with child literature.

Early studies on children's narratives focused mainly on story characters, but Berman (1988) started focusing on events by eliciting stories with the wordless picture book ”Frog, Where Are You?” (Mayer, 1969), which depicts a story of a length and complexity beyond what is generally used for children. In Berman's (1988) study, children as young as 3 years of age seldom digressed from the content of the story book and they showed command of a wide range of simple-clause constructions, inflectional markers and grammatical functions. However, young children's narratives differ both on a global and on a local level from older children, who in turn differ from adults' accounts of the events. From school age, the children in Berman's study made explicit reference to the search motif and overtly marked events as following sequentially one after another (ibid.).

Narrative ability has been shown to predict later academic achievement, for instance literacy skills (e.g. Griffin et al., 2004; Wellman et al., 2011) and mathematical ability (e.g. O'Neill, Pearce, & Pick, 2004). Narrative comprehension as well as production require organizational skill and depend particularly on frontal cortical activation (e.g. Friend & Bates, 2014). There also seems to be a complex relation between children's narratives, language proficiency and Theory of Mind (see e.g. Astington & Baird, 2005; Astington & Jenkins, 1999).

2.2.4. Language and socioeconomic status

It seems well established that aspects of parental socioeconomic status (SES) are connected to children's acquisition of language and EF skills (e.g. Hoff, 2003, 2006; Lervåg, Dolean, Tincas, & Melby-Lervåg, 2019; Sarsour et al., 2010), and the risk associated with lower SES may become more important as a causal factor in language difficulties as children get older (Rescorla, 2011). However, more recent studies have found support for a view in which it is not wealth *per se*, but rather aspects of parents' educational behavior, in other words how parents shape their children's physical, social, cognitive and cultural environment, that have an impact on children's language development (Rindermann & Baumeister, 2015). Recent work also suggests that strong statistical learning abilities can attenuate disadvantages in language outcomes relating to SES (Eghbalzad, Deocampo, & Conway, 2021), providing further evidence of complex interactions between cognitive aspects and the environment. It should also be noted that results are somewhat divergent when it comes to whether all aspects of language are associated with parental SES (see Hoff, 2006, for a summary).

A general problem in relation to SES brought up by among others McKean and colleagues (2015) and addressed in Study III, is that socially disadvantaged groups may be less inclined to participate in research and may have higher levels of attrition. Additionally, studies have used different measures of SES, making comparisons and generalizations across cultural contexts difficult (Kidd et al., 2018, Nielsen et al., 2017). Furthermore, it may be misleading to compare SES across different contexts as the same measure may still reflect different underlying societal structures. In Sweden for instance, higher education is free of charge and high-quality childcare is heavily subsidized (see also chapter 5).

Most studies investigating the association between aspects of SES and child language development have been conducted in the North American context and Swedish studies that have examined effects of socioeconomic status (SES) on aspects of language development are relatively scarce. Westerlund and Lagerberg (2008) found no SES-related differences in expressive vocabulary in Swedish 18-month-old children. Bohnacker, Lindgren, and Öztekin (2016) examined productive vocabulary in bilingual children in Sweden, aged 4–6 and found no association to SES. Bruce, Thernlund, and Nettelbladt (2006) found a weak correlation between SES and expressive language skills in a sample of school-aged Swedish children with attention deficit hyperactivity disorder (ADHD). It should be mentioned that the socioeconomic differences in Sweden are smaller than in most other OECD countries despite a surge of income inequality since the early 1990s. Poverty rates are among the lowest, women have a high employment rate compared to other OECD countries and unemployment is receding, although it remains high for foreign-born residents (OECD 2017). Furthermore, a vast majority of Swedish children attend preschool more or less full-time from an early age.

In Studies I, III and IV of this thesis, a composite SES measure comprising information of both parents' (when applicable) income and education was used (see also Gerholm et al., 2018), whereas separate SES measures were used in Study II. In Study I, there was no effect of SES on children's language or EF. In Study II with a vastly larger sample, aspects of SES were significantly associated with receptive vocabulary and morphosyntax. In Study III, SES was hypothesized to act as a moderating factor for intervention outcomes, but there were no significant intervention results. Neither was there a significant effect of SES on language composite measure at pretesting. However, we found significant SES differences between intervention groups as baseline, in spite of randomization, which may have affected intervention uptake. Furthermore, higher SES was associated with spending more time per week at preschool, and monolingual children had significantly higher SES than multilingual children. Study IV showed that SES significantly predicted children's level of explicitness in explaining a fictional false belief.

2.2.1. Language and potential differences between girls and boys

With regard to potential differences between boys and girls in language skills, there are widespread beliefs that boys lag behind girls. Additionally, the prevalence of language disorders, dyslexia, ADHD and autism spectrum disorders is higher in boys than in girls. However, results are somewhat divergent and possible interactions between SES and sex have seldom been investigated (see Barbu et al., 2015, for a summary). Even in the cases in which reliable sex-related differences have been found, many of the effects are small (e.g. Tenenbaum, Aznar, & Leman, 2014).

Few Swedish studies have investigated potential sex-related differences among typically developing children with regard to language ability, but existing Swedish research does indicate a female advantage. Eriksson and colleagues (2012) examined emerging language skills by collecting data from parents of a large sample of children aged 8–30 months across 10 language communities, including Sweden, and found a female advantage in 18-months-old Swedish children with regard to early communicative gesture, productive vocabulary and the ability to combine words, thus indicating that sex-related differences may be present at an early age. Westerlund and Lagerberg (2008) investigated vocabulary in 1 091 Swedish children aged 18 months and found that girls scored higher on parental ratings of expressive vocabulary than boys. Another Swedish study in which 1 134 parents rated their child's vocabulary, grammar and metalinguistic skills showed that girls scored higher than boys on all scales (Eriksson, 2017). Bruce et al. (2006) found that school-aged girls outperformed boys in literacy skills.

The studies in this thesis reveal a potential female advantage for nonverbal communication skills (Study I), which is however not confirmed in a larger sample (Study III). Girls perform better than boys with regard to receptive vocabulary and morphosyntactic accuracy (Study II), but there are no sex differences in relating a fictional false belief (Study IV).

2.2.2. Language and bi-/multilingualism

In 2017, the proportion of children in Swedish schools with another first language than Swedish was approximately 25 % and more than 100 different languages are represented (Håkansson, 2019). The circumstances of growing up multilingually vary enormously and it has been suggested that it is not meaningful to consider multilingual children as one group or to generalize about the effect of bilingual exposure on language development (e.g. Hoff, 2006; Lindgren, 2018). Given sufficient input, the rate and course of language development in bi- or multilingual children has been described as largely similar to monolingual development (e.g. Petitto et al., 2001). However, the effects of bilingual exposure on language development depend on the language domain(s) under consideration and is also affected by how similar the languages are. For bilingual children in Sweden, Håkansson and Nettelbladt (1993) claimed that there was no fundamental difference in the acquisition of syntax when comparing first language acquisition with second language acquisition in a group of monolingual and bilingual preschool children. Lindgren (2018) found no differences in vocabulary size when comparing monolingual Swedish and bilingual Swedish-German children. However, Swedish-Turkish children lagged behind and the author emphasizes the need to take socioeconomic factors and amount of linguistic input into consideration. A longitudinal study including nearly 2000 Australian children showed that children who had English as a second language performed low on language tests at age 4 but also had the fastest rate of progress and had caught up with peers at age 7 when adjusting for socioeconomic status (McKean et al., 2015). Dick and colleagues (2019) were able to replicate previously reported disadvantages in vocabulary, that were however mitigated when controlling for SES and intelligence. Additionally, quality of classroom interactions and age of preschool enrolment have shown to be important for vocabulary in the majority language in dual language learners with low exposure to the majority language (Kohl, Willard, Agache, Bihler, & Leyendecker, 2019).

In Study I, there were no significant differences on any of the language measures when comparing mono- and multilingual children. However, in Study II, when controlling for parental education and income as separate measures, multilingual children had significantly lower receptive vocabulary scores. Study IV revealed no significant effect of being multilingual on children's proneness to relate a fictional false belief in narrative.

2.3. Development of executive functions

In parallel to language development, the development of EF seems to be the result of complex interactions between a number of causal mechanisms. The multitude of theories regarding the basis for EF and the exact nature of EF will to some extent affect the description of development (see also chapter 3). In developmental psychology, the voluntary control of emotion and cognition has often been referred to as self-regulation, whereas in adults the same set of functions is often called self-control or willpower. However, there does not seem to be a strict dividing line between these different concepts used for children and for adults respectively, see also Petersen and Posner (2012).

Since EFs show both unity and diversity (Miyake et al., 2000), some EF abilities develop early but altogether; EFs, including selective attention, continue to develop at least into adolescence (e.g. Klenberg et al., 2001). Traditionally, EFs have been thought to be absent in very young children, but during the recent decade or so, scholars have found signs of rudimentary aspects of EF even in young babies. Infants exhibit approach and withdrawal tendencies that could form a basis for self-regulation, but by and large, it is often the caregiver's intervention that regulates the child's behavior during infancy (Bernier, Carlson, & Whipple, 2010; Posner, Rothbart, Sheese, & Voelker, 2012). There are however signs that some very basic EF skills can be present in infants as young as 7 months, and Posner and colleagues have argued for a transition between two executive control networks during early childhood, so that during infancy, control is exercised by the orienting network but this later shifts towards the executive network (Posner et al., 2012; Rothbart et al., 2011). Wynn (1992) and Berger, Tzur, and Posner (2006) conducted experiments with infants, who were presented with puppets which were then hidden behind a screen. A hand reached in and either added or removed a puppet. When the screen was lifted again, 5-month-old infants looked longer when the wrong number of puppets was shown than when the correct number was shown (Wynn, 1992), and when brain activity was measured with EEG, 6–9-month-old infants had the identical scalp pattern as adults in error detection tasks (Berger et al., 2006). Sheese, Rothbart, Posner, White, and Fraundorf (2008) showed that 6–7-month-old infants who showed higher levels of anticipatory looking were more likely to regulate approach tendencies when presented with novel toys. Bernier and colleagues (2010) investigated associations between the quality of mother–child interactions early in development and children's subsequent EF in a middle-class Canadian sample and showed that aspects of maternal care were connected to early development of EF. The most robust finding was that autonomy support, which in this case refers to parental behaviors aiming at supporting children's goals, choices and sense of volition, seemed to be the aspect of parenting that was most clearly associated with child EF. The authors discussed the possibility of bidirectional effects between parenting and child EF: favorable circumstances in the infant's environment may stimulate brain development, which in turn may contribute to the maintenance of successful parent–child interactions, giving the child increasing opportunities to self-regulate (ibid.).

There seems to be a developmental spurt in EF performance during the age span 3 to 6 years (e.g. Carlson, 2005; Garon, Bryson, & Smith, 2008), and both behavioral and functional data indicate substantial development of EF from infancy to childhood (see Garon et al., 2008 for a review). For instance, when presented with a cognitive flexibility task that requires the child to shift rules, a 3-year-old is likely to perseverate, whereas a typically developing 5-year-old can manage to switch flexibly between rules (e.g. Doebel & Zelazo, 2015). EF evolves further during middle childhood. For instance, Park, Weismer and Kaushanskaya (2018) found continued development of cognitive flexibility and working memory in a sample of 8–12-year-olds, whereas inhibition stabilized in early school years (at least in monolingual participants). The prolonged development of EF holds in particular for some aspects of cognitive flexibility, which show qualitative differences even when comparing adolescents and adults (e.g. Davidson, Amso, Anderson, & Diamond 2006). However, results from neuroimaging suggest that the neural architecture that supports EF is in place by middle childhood, suggesting that further improvements to adulthood are due to quantitative rather than qualitative changes within brain networks (e.g. Engelhardt, Harden, Tucker-Drob, & Church, 2019).

A prolonged development specifically for selective auditory attention is indicated by both behavioral and neurophysiological studies (see Sanders, Stevens, Coch, & Neville, 2006, for a summary). This development can be said to have two components: the ability to selectively attend the relevant stimuli and the ability to successfully ignore or suppress stimuli that are irrelevant. An early child experiment using ERP as well as behavioral measures to investigate selective auditory attention was conducted by Berman and Friedman in 1995. Participants (young school-aged children, teenagers and young adults) were presented with sequences of low- and high-pitched tones or consonant-vowel syllables and were required to attend to either the tones or the syllables in order to detect a deviant target embedded within the attended sequence. The negative difference amplitude at 200–400 ms increased from childhood to young adulthood, more markedly so for the syllables. Berman and Friedman (1995) furthermore suggested that with increasing age, there is an improvement in the narrowing of the attentional focus. ERP studies indicate that with increased age, it is specifically the ability to suppress irrelevant stimuli that improves (e.g. Karns, Isbell, Giuliano, & Neville, 2015; Sanders et al., 2006). Jones, Moore, and Amitay (2015) conducted a tone-in-noise detection experiment with children aged 4–11 and adults. At 9–11 years of age, performance was adult-like and this was explained solely by improvements in selective attention, specifically improvements in the ability to ignore noise of certain frequencies. Robinson, Hawthorn, and Rahman (2018) found that young children had more difficulty dealing with auditory than visual distractors in a visual selective attention experiment, indicating modality-specific aspects of interference suppression.

In the studies included in this thesis, age was expected to be significantly associated with EF, which was indeed the case: Study I showed that age was positively associated with performance on a composite measure of EF, and age predicted EF performance in pre- as well as posttest data (Study II and Study III). However, the selective attention measure was not associated with age.

2.3.1. Underlying structure of EF

From an empirical as well as a theoretical perspective (see also chapter 3) it is still unclear if and when EF is best conceived of as a unitary structure in early childhood or if and when one can observe clear separation into the three core EF components, cognitive flexibility/shifting, inhibition and working memory (or, for that matter, into other possible EF components). To clarify the underlying structure of EF in young children, one needs to conduct an array of tests for each suggested subcomponent of EF and then apply factor analytic methods. Each test needs to be as "pure" as possible, both with regard to how well it measures the possible subcomponents of EF and how little it places demands on language skills.

It has been suggested that EF is unitary in young children and then undergoes increased separation into separate components (e.g. Brydges et al., 2014; Wiebe, Espy, & Charak, 2008). However, two-factor models have also been suggested: Lerner and Lonigan (2014) found separable inhibition and working memory components in preschool children with typical development. Usai, Viterbori, Traverso, and De Franchis (2014) assessed EF in 175 Italian children assessed at 5 and 6 years of age and found that inhibition was distinguished as a separate factor whereas working memory and shifting emerged as a unitary component, and ten Braak, Kleemans, Størksen, Verhoeven, and Segers (2018) found a distinction between attentional and behavioral control in Dutch 6-year-olds, and found furthermore that these components related differentially to literacy and math development. With regard to the Swedish context, Brocki, Eninger, Thorell, and Bohlin (2010) found empirical support for both inhibition and attention as foundational for more complex EF processes in a longitudinal study of typically developing Swedish 5–7-year-old children. Howard, Okely and Ellis (2015) investigated EF in 3–4-year-old Australian children, separated in narrow age bands and showed that EF components in younger children were independent of one another whereas EF components of older children were increasingly related. The authors suggested that a single trajectory of increased differentiation of EF components does not fully explain EF development during preschool years.

The current studies used composite measures of EF; in Study II, III and IV, results from all behavioral tests of EF, except backward digit span, were included in the EF composite measure, whereas in Study I, both forward and backward digit span tasks were excluded from the EF composite; see chapter 5 for further details about assessment materials.

2.3.2. EF and socioeconomic status

International studies have found clear associations between EF and SES (e.g. Noble, McCandliss, & Farah, 2007; St. John, Kibbe, & Tarullo, 2019), including results which overlap between effects of SES and verbal ability on EF development (Hughes, Ensor, Wilson, & Graham, 2009). For selective auditory attention specifically, it has been shown that children from lower-SES backgrounds have a reduced ability specifically when it comes to filtering out irrelevant information (e.g. Stevens, Lauinger, & Neville, 2009).

A Finnish study including 400 children between 3 and 12 years of age, conducted by Klenberg and colleagues (2001), found a stronger relation between parental education and EF than to attention, which they considered a separate measure. Since studies on EF including Swedish children are relatively scarce, little is known of possible connections to SES. Bruce et al. (2006) found no associations between SES, measured as the parents' highest occupational level, and ADHD problem areas in a sample of school-aged children with a diagnosis of ADHD.

With regard to connections between SES and EF and selective attention, Study I found no such association, whereas Study II and III showed that SES significantly predicted EF composite measure in pretest as well as posttest data. Study II furthermore revealed that SES was associated with auditory selective attention measured with ERP.

2.3.3. EF and potential differences between girls and boys

Little is known about potential differences between Swedish girls and boys in EF skills and previous work diverges when it comes to sex-related differences in EF, but several studies, particularly those conducted in the United States, have indicated a female advantage in EF (e.g. Fuhs & Day, 2011; Mulder et al., 2014). A study by Klenberg and colleagues (2001) also indicated that girls outperformed boys on a majority of EF subtests (the authors themselves point out that these subtests included semantic and phonemic fluency tasks, both which could be re-interpreted as language tasks or at least heavily dependent on language skills). Jensen, Holm, and Bremberg (2013) found that girls performed better than boys on the Strengths and Difficulties Questionnaire, which to some extent assesses aspects of EF. On the other hand, no EF differences were found in a sample of German children aged 3 to 4 (Slot and von Suchodoletz 2017). Neither did Gestsdottir and colleagues

(2014) detect any sex-related differences in EF in French or German children, however, there was a female advantage in EF for children from Iceland. Grissom and Reyes (2019) concluded in their recent review that there is little support for significant sex differences in EF.

In the studies included in this thesis, results regarding sex differences and EF were not conclusive; in Study I, there was a male EF advantage, whereas Study II showed a female advantage that was however not present in posttest data (Study III).

2.3.4. EF and bi- or multilingualism

There are several studies reporting better EF skills in bi- or multilingual children compared to monolinguals, both on behavioral and electrophysiological measures (e.g. Adesope, Lavin, Thompson, & Ungerleider, 2010; Barac, Moreno, & Bialystok, 2016). The theoretical idea behind an advantage in EF in multilingual individuals compared to monolinguals is that managing several languages puts demands on the cognitive control system, especially when switching between languages and inhibiting the language not currently in use, which in turn is assumed to transfer to tasks that recruit the same EF network (e.g. Kroll, Bobb, Misra, & Guo, 2008). Results regarding stronger EF in multilingual individuals have however not been easy to replicate. Duñabeitia et al. (2014) conducted a large-scale study with school-aged children and adolescents and found no support for a bilingual advantage. More recently, Borragan, Martin, de Bruin and Duñabeitia (2018) suggested that the inhibitory processes at play in bilingual individuals are domain-specific for language. Dick and colleagues (2019) investigated EF in a U.S. sample comprising over 4 500 children aged 9–10 and found little evidence for any bilingual advantage for inhibitory control, attention or cognitive flexibility (working memory was not assessed in the study). A recent Swedish study examining older bilingual age groups also failed to find any beneficial effects of bilingualism on EF (Sörman, Hansson & Körning Ljungberg, 2019). A large meta-analysis, which took publishing bias into account, concluded that there are no beneficial effects of bilingualism on EF that last into adulthood (Lehtonen et al., 2018).

In the current studies, no significant effects of being multilingual were found with regard to EF performance or selective attention.

2.4. Development of mathematical ability

Mathematic skills are not a main focus for the studies in this thesis. However, children's performance on a mathematic test was one of the outcome measures in Study III; the intervention study and an overview of mathematical development, focusing on number sense and its potential links to SES, sex and multilingualism is therefore provided.

Strong mathematical skills are vital both for the individual and for society and build upon domain-general skills as well as domain-specific abilities. Mathematical ability has links to both language, EF and general intelligence and is described as an inevitable feature of children's cognitive development (e.g. Ginsburg, Cannon, Eisenband & Pappas, 2006; Harvey & Miller, 2017). Math is also associated with false belief understanding (e.g. Blair & Razza, 2007). In general, young children are more competent in key aspects of early mathematics than previously thought, and during preschool years, children spontaneously develop every-day, informal mathematics without explicit teaching (Ginsburg & Amit, 2008). Children are also able to learn rather complex mathematics if they are taught, but individual differences in mathematical knowledge are evident already at 3–4 years of age, and children with poor math skills fail to catch up during formal schooling (e.g. Aunio & Räsänen, 2016; DeFlorio & Beliakoff, 2015; Klibanoff, Levine, Huttenlocher, Vasilyeva, & Hedges, 2006).

Among domain-specific mathematic skills, number sense is considered the most powerful specific numerical ability, which lays the foundation for learning formal mathematical concepts (e.g. Aunio, Tapola, Mononen, & Niemivirta, 2016; Aunio & Räsänen, 2016). Early accounts of number sense include Piaget's (1967) suggestion that children do not reach a proper understanding of the concept of number until they pass the number-conservation task at approximately 6–7 years of age, in other words when they can perceive that visual transformations do not affect the numerical properties of an array of objects. However, experimental studies have shown that even infants show signs of rudimentary number sense, and failure to pass the number-conservation task may be related to visuospatial cues negatively affecting performance, rather than the absence of a number sense. The Piagetian shift between two separate stages of development can rather be conceptualized as a progressive development toward higher levels of numerical abstraction (see also Viarouge, Houdé, & Borst, 2019).

Newborns can discriminate two from three dots (Antell & Keating, 1983), 5-month-old infants are able to calculate the results of simple arithmetical operations, suggesting that they possess true numerical concepts (e.g. Wynn, 1992) and 6- to 9-month-olds can detect simple arithmetic errors (e.g. Berger, Tzur, & Posner, 2006). It is suggested that these early signs of number sense build on preverbal representations of quantities (e.g. Izard, Sann, Spelke, & Streri, 2009), but there also seems to be a tight interplay between verbal and nonverbal quantification (Mix, Sandhofer, & Baroody, 2005).

2.4.1. Mathematics and SES

Several studies have shown that children from lower-SES backgrounds enter school with lower levels of mathematical skills (see Blevins-Knabe, 2016, for a summary). Variations in the home numeracy environment may be a factor, where parents from lower SES may to a lesser extent highlight mathematical information that is accessible in the environment, less often engage in counting or calculation games and provide fewer learning opportunities connected to math (e.g. Lee & Kotsopoulos, .2016). In addition, parents' beliefs about early math development seem to vary as a function of SES (e.g. DeFlorio & Beliakoff, 2015). However, Valero and colleagues (2015) concluded that research on SES and mathematical achievement comes mainly from English-speaking countries.

In Finland, SES effects on math seem smaller than in other countries, and it is suggested that the Finnish early childhood education system, which in many ways resembles the Swedish system, potentially balances out consequences of socioeconomic differences (Aunio et al., 2016). Major revisions of the Swedish preschool curriculum in 2011 meant that the objectives for children's mathematical development were made much clearer, and it now states that preschool should provide every child with opportunities to develop the ability to use mathematics to explore, reflect and solve problems and to understand time, space and shapes and basic properties of quantities, patterns, number concepts etc. However, quantitative research on Swedish preschoolers' math ability in relation to SES is scarce.

2.4.2. Math and potential differences between girls and boys

Previous work diverges when it comes to gender differences in mathematics; there are results pointing to a male advantage, a female advantage or no or trivial differences between boys and girls. The pattern may also vary depending on age of assessment and depending on culture (see Kersey, Graham, Csumitta, Libertus, & Cantlon, 2018, for a summary). However, recent studies on children and adults, including meta-analyses of unpublished as well as published data, indicate the absence of gender differences in mathematical ability. Bakker, Torbeyns, Wijns, Verschaffel, & De Smedt, (2019) examined math ability in Belgian 4–5-year-olds and showed that children's early numerical competencies are characterized by gender equality. A relatively recent study used data from over 500 children aged 6 months to 8 years, including unpublished data, to examine gender differences in mathematical cognition and found no differences between boys and girls in early mathematical ability (Kersey et al., 2018). Neither a meta-analysis of 242 studies nor an analysis of very large data sets of U.S. adolescents indicated any gender differences (Lindberg, Hyde, Petersen, & Linn, 2010).

2.4.3. Math and bi- or multilingualism

There is strong evidence suggesting that bilingualism *per se* does not impact mathematical reasoning (e.g. Moschkovich, 2014). Limitations in second language (L2) proficiency may influence performance on verbal components of numerical skills when assessed in L2, but Bonifacci, Tobia, Bernabini, and Marzocchi (2016) showed that bilingual preschool-aged children did not differ from monolingual peers in non-verbal components such as quantity comparison. Additionally, working memory may act as a predictor of math-solving accuracy in both languages in emerging bilinguals (Lee Swanson, Kong, & Petcu, 2019).

2.5. Concluding remarks

A view of development as dynamic and contextualized warrants investigation of the language–EF relationship in Swedish typically-developing young children – a population which has not been studied extensively with regard to language development and which has seldom been examined from a perspective focusing on both language and EF. Both language and EF seem to be connected to basic forms of attention as well as to more sophisticated forms of shared intentionality, and narrative skill in particular could perhaps be conceptualized as constituting a language–EF–social cognition interface.

The underlying structures of language and EF are not clear: Even as we observe rapid development in the overt behaviors and abilities which we refer to as language or EF, the nature of the covert mechanisms and structures providing the basis for those behaviors undergoes qualitative change. A theoretical account of how language and EF are connected in early childhood needs to consider the dynamics of development, and further empirical work is needed to establish the specifics of the complex interplay between different components of linguistic, cognitive and social development.

3. Theoretical perspectives

In this chapter, I start by briefly presenting two main theoretical perspectives on language: the generativist view and the emergentist, or usage-based approach. Although the theoretical approaches diverge quite substantially in their view of the fundamentals of language, it can be argued that they mostly deal with different aspects of language, or that they are interested in answering diametrically different questions about language. Whereas generativists focus on language as a formal, abstract system, usage-based proponents are more interested in language use and meaning. Next, I describe some of the more influential models relating to EF, including a general framework for attention (Posner & Petersen, 1990).

Considering the often-reported associations between EF and different aspects of language skills, it is surprising that few of the existing EF models incorporate language to a larger extent, or that scholars have not to a larger degree created and tested models which attempt to clarify the nature of the relationship. Psycholinguistic research has to some extent shed light on the potential associations between more specific aspects of language and EF, and a brief summary of selected work is provided, before I outline the potential relationships between language and EF. The chapter concludes with a note on the connections between mathematics, language and EF.

3.1. Language

> Only the most preliminary and tentative hypotheses can be offered concerning the nature of language, its use and its acquisition. (Chomsky, 2006, p. 23)

The claim that there are of some kinds of innate mental structures which, in one way or another, are concerned with language is not particularly controversial. The debate rather concerns whether or not these structures are specific to language or if they can be viewed as part of a general cognitive capacity. The theoretical perspective on language will affect which aspects of development are considered important, as well as the underlying reasons for development. The point of departure with regard to the nature of language has consequences for the interpretation of associations between language and (other) cognitive functions, such as EF. The view of what ‘language’ is also has consequences for the possible theoretical underpinnings of such associations.

3.1.1. Generativist approaches

Noam Chomsky is sometimes said to have revolutionized the field of linguistics since he presented his manifesto *Syntactic Structures* in 1957, which in turn was a reaction against Skinner’s *Verbal Behavior*, published the same year. Core ideas of Chomskian theory include transformational-generative grammar, an innate language faculty, dedicated to the acquisition of language, and the claim that language use in adulthood is mostly a mental exercise.

> Now let’s take language. What is its characteristic use? Well, probably 99.9 percent of its use is internal to the mind. (Chomsky & McGilvray, 2012, p. 11).

Later accounts of a human-specific language faculty focus only on the concept of recursion, which is also held to be the only uniquely human property of the faculty of language (e.g. Hauser, Chomsky, & Fitch, 2002). Chomsky states that learning about the mechanisms of language is informative also with regard to the nature of the human mind, since principles of language reflect the mind (e.g. Chomsky, 2006), although one may add that he is not entirely clear exactly in what way. Chomsky characterizes language as a system of knowledge or competence, focusing on linguistic rules and forms, rather than linguistic performance. Linguistic performance, in other words the actual use of language, may be flawed due to influence from memory or attention restrictions, other aspects of non-linguistic cognition such as pragmatic abilities or simply maturational aspects (see also Tomasello, 2000), whereas inadequate competence is viewed as a deficiency in language-specific parts or networks of the brain. Performance restrictions explain why adult speakers do not speak in perfect sentences all the time, and, according to some generativist accounts of language development, why children make syntactic errors during the course of typical language development (e.g. Chomsky, 2006). There are also scholars who argue in favor of a competence deficit approach to explain children’s grammatical errors (see Yang, 2002, for a summary). The separation of language competence versus language performance has been criticized, since the notion is unfalsifiable, similar to Freudian psychology (Ibbotson & Tomasello, 2016). From a developmental perspective, it has also been argued that a competence–performance distinction is not meaningful to understand development (see also Section 2.1 above).

Chomsky himself has not focused particularly on child language acquisition or development, but other scholars in the generativist field have done so to a greater extent. For instance, Yang, Elman, and Legate (2015) assume that statistical properties of the linguistic input play a vital role in language acquisition and they acknowledge that the generative approach has rarely examined quantitative aspects of the input. The variational model of language acquisition (VLM) proposed by Charles Yang (2002) employs the metaphor of competition to explain the mechanisms behind language (or rather, syntax) acquisition. Possible grammars are constrained by innate, language-specific structures, but the VLM also incorporates the statistical properties of the primary linguistic data. The child hears some input and then in a probabilistic manner selects a grammar to analyze this input. Grammars that succeed in analyzing a sentence are rewarded, while those that fail are punished. The learning scheme in itself is very general, works across cognitive domains and is not human-specific (e.g. Yang, Elman, & Legate, 2015), thus opening up for more domain-general mechanisms in language acquisition. The VLM is also able to explain gradualness in child language, since Yang opposes the assumption of transformational learning (Yang, 2002).

A generativist perspective of language in relation to EF would limit the object of interest to mainly syntactic aspects and their potential associations with EF. Hypotheses regarding the direction of the relationship would perhaps mainly be that language-specific processes exert some influence on (other) cognitive mechanisms, but underlying reasons for a syntax–EF relationship would need further consideration, not least since some generativist scholars have claimed that general cognition works separately from language (e.g. Pinker, 1999). Any specified theory of the language–EF relationship would from a generativist point of view be facilitated if one adopts the concept of a Broad Language Faculty, which has some overlap with other cognitive functions (e.g. Hauser, Chomsky & Fitch 2002).

3.1.2. Emergentist approaches

> …children are not born with a universal, dedicated tool for learning grammar. Instead they inherit the mental equivalent of a Swiss Army knife: a set of general-purpose tools — such as categorization, the reading of communicative intentions and analogy making, with which children build grammatical categories and rules from the language they hear around them. (Ibbotson & Tomasello, 2016)

Emergentist approaches, such as usage-based theories about language, focus on how meaning-based grammatical constructions emerge from language use (Tomasello, 2003) and such approaches share the common assumption that language can be learned from the linguistic input children receive, supported for instance by mechanisms such as statistical learning (e.g. Saffran, Aslin, & Newport, 1996). Critics of usage-based accounts argue however that there is no known general learning mechanism that can acquire language only based on positive or negative evidence (e.g. Hauser, Chomsky, & Fitch, 2002).

From an emergentist point of view, diachronic language change, child language acquisition and language in real-time conversation are all determined, shaped, or controlled by communicative function (e.g. MacWhinney & O'Grady, 2015), which is in line with the perspective adopted in this thesis. Instead of separating language from other cognitive abilities, advocates of usage-based theories rather claim that memory and attention may be integral to building a language. Social abilities, such as the ability to understand others' communicative intentions, are also important in the toolkit for learning language (see also Section 2.1.2 above). In this perspective, linguistic competence means mastery of the linguistic symbols and constructional schemas of a language, a competence which in turn is based on general cognitive abilities, although they may take on some special characteristics in linguistic communication (e.g. Tomasello, 2000). Proponents of a usage-based perspective claim that humans are not born with some specific innate capacity to form sentences using abstract syntactical rules. Rather, children acquire language by first learning simple patterns and in their earliest linguistic productions there is no evidence of abstract syntactic categories. They then gradually come to understand the rules (e.g. Ibbotson & Tomasello, 2016; Tomasello, 2000). The mechanisms employed by an infant to organize what he/she hears in linguistically relevant ways does not need to be based on some language-specific mechanism (see also Altmann, 2001).

An emergentist perspective on language acquisition goes hand in hand with a general view on development as dynamic and self-organizing, but closer specification is nevertheless required as to *why* aspects of language and EF would be connected and, above all, *how* the seemingly interdependent development of these aspects of cognitive ability takes place. A view on development in general as emergent and of language as part of, not separate from, other cognitive abilities, potentially makes it more difficult to delineate which processes should be considered linguistic as opposed to related to EF. Clear definitions and operationalizations are therefore vital in any attempts to clarify the course and cause of development.

3.2. Executive Functions

Why is it the case that there are several theories and models of EF and why has research not come further in defining EF and in finding its neural underpinnings? In this section I will highlight some influential models with regard to the nature and development of EF.

There are several challenges with EF as a concept; some of these challenges include the absence of complete consensus regarding how EF should be defined and operationalized and the lack of correlation between studies in which EF is assessed with experimental tasks or tests compared to EF based on parent and teacher reports (see also Section 4.3 below). An array of cognitive models and theories regarding the structure of EF has been suggested, with two broad approaches to the development of EF, one which conceives of EF as a unitary construct with constituent subprocesses (e.g. Baddeley & Hitch, 1974; Norman & Shallice, 1986; Posner & Rothbart, 1998; see also Garon, Bryson, & Smith, 2008 for a review) and a contrasting view which considers EFs as dissociable processes (e.g. Carlson & Moses, 2001; Diamond, 1991). The models and theories attempting to describe the nature of EF have to a varying extent been confirmed by neuroscientific findings regarding neural pathways and patterns of activation.

There are separate models explaining the components, functions and development of selective auditory attention (e.g. Driver, 2001; Shinn-Cunningham & Best, 2015), as well as models of EF in which attention in a broader sense is seen as a fundamental process which lays the foundation for more complex EF processes such as working memory (Norman & Shallice, 1986; Posner & Rothbart, 1998), or models in which aspects of attention are specifically described (e.g. Cowan, 1988). Some models focus on the foundational role of inhibition for development of EF and also explicitly mention language as an integrated part of EF (Barkley, 1997b), whereas yet other models claim that language, in terms of reflection and the ability to reprocess information, is the foundation for flexible control of attention/EF (e.g. Zelazo, 2015).

Several studies have shown that EF is linked to children's Theory of Mind understanding (see also Section 2.1.2), and there seems to be a specific developmental link between Theory of Mind development and improvements in EF at around age 4 (see e.g. Perner & Lang, 1999, for a review). In parallel to the discussion about the direction of the relationship between language and EF, some claim that Theory of Mind predicts EF, or even that Theory of Mind is a prerequisite for EF (e.g. Chasiotis, Kiessling, Hofer, & Campos, 2006; Perner & Lang, 1999), whereas some are in favor of the opposite view, stating that aspects of EF are required for successful performance on Theory of Mind tasks (e.g. Austin, Groppe, & Elsner, 2014; Carlson & Moses, 2001; Jacques & Zelazo, 2005). EF skills are also highly related to children's ability to resolve conflict, and strong EF skills in childhood are associated with fewer antisocial behaviors in adolescence, indicating that EFs are crucial for child socialization (see Petersen & Posner, 2012, for a review).

3.2.1. Models of Executive Functions

In the upcoming section, I describe some of the more influential models relating to executive function and attention, starting with a general framework for attention (Posner & Petersen, 1990). Most of the models included in this account discuss development and/or EF in childhood to some extent, exceptions being models by Norman and Shallice; and Cowan, which are however included in this review since they both bring up aspects of selective attention.

Models differ in their conceptualization of EF – either as a network of processes or as some kind of specific module – and in what aspect of EF is considered more important or potentially hierarchically superordinate other EF components. Models also differ with regard to the extent to which they are empirically supported. During recent decades, in conjunction with the advancements in neuroimaging techniques, some of the influential theories regarding EF summarized below, have been challenged. For instance, neurally-based models of working memory (e.g. D'Esposito, 2007; see also Section 3.2.1.9 below) are not congruent with some wide-spread cognitive accounts of the same construct (e.g. Baddeley, 2000; Baddeley & Hitch, 1974; Section 3.2.1.5 below). However, paraphrasing Adams (2014): To discern the difference between cognition and processes that provide causal support for cognition, neuroimaging data do not suffice: we need a cognitive theory.

3.2.1.1. Attention: general framework

Posner and Petersen (1990) presented three fundamental findings regarding attention in general, predominantly supported by findings from behavioral studies of visual attention. First, they claimed that the attention system was anatomically separate from data processing systems; in other words, attention was conceived of as having its own identity just like sensory or motor systems. Second, they meant that attention is carried out by a network of brain areas. Third, these areas carry out different functions, entailing that the attention system can be divided in three subsystems: the *orienting* network, focused on the ability to prioritize sensory input by selecting a modality or location, the *detecting* network, which detects signals for conscious processing and the *alerting* network, enabling us to maintain a vigilant state (ibid).

An interpretation of the framework proposed and later revised by Posner and colleagues (Posner & Petersen, 1990; Petersen & Posner, 2012; Posner, Rothbart, Sheese, and Voelker, 2012) would be that EF in early childhood are based on orienting, in other words, on aspects of selective attention. In their updated version of the human attention system, Peterson and Posner (2012) suggested that the detecting network is better conceptualized as two different *executive* networks that act relatively independently in producing top-down control. One system deals with maintenance and the other is believed to relate to task switching (ibid.). These two networks may however have a common origin early in development. This topic was elaborated on in a paper by Posner et al., 2012, in which the authors suggested that during infancy, executive control systems depend primarily upon one brain network, which is involved in orienting to sensory events. At 3–4 years of age, the executive networks increasingly control cognition and emotion (ibid.).

3.2.1.1.1. Selective attention

The term 'selective' refers to a specific kind of attention, different from changes in general arousal or states of consciousness (Serences & Kastner, 2014). Selective attention has been discussed since the early 20th century (see Driver, 2001, for a review), and Broadbent's filter theory, introduced in 1958, was one of the first theoretical accounts that related psychological phenomena to information-processing concepts. The original model conceptualized auditory selective attention as a strict filter that was thought to reject unwanted information based on physical parameters such as location, pitch and loudness (see also Shinn-Cunningham & Best, 2015, for a summary). Broadbent (1958) furthermore suggested two stages of perceptual processing, the first one concerned with processing of 'physical' properties from all incoming stimuli, whereas the second stage was conceived of as more limited in capacity, protected from overload by a selective filter. However, Broadbent admitted that certain stimuli may capture attention involuntarily; in other words what is attended and what is rejected/suppressed depends both on volitional attention and inherent stimulus salience (ibid.). Treisman (1960) suggested that the filter attenuates irrelevant stimuli rather than filtering them out completely. In this view, the second stage of processing would receive input from both attended and unattended stimuli, and the unattended would in some, exceptional cases be possible for the listener to identify, for instance as a result of priming (Driver, 2001; Shinn-Cunningham & Best, 2015; Treisman, 1960). This position stresses the role that partial information (attenuated inputs) and priming can have on psychological processes.

Shinn-Cunningham and Best (2015) provide an overview of auditory selective attention research during the last decades and show that there is growing evidence for a view of selective attention where the focus of attention is determined by the interplay between exogenously and endogenously guided attention. The main unit of auditory attention may be an auditory object (i.e. a collection of attributes), but a listener can still use top-down processes to selectively attend to specific acoustic dimensions of the stimuli as well as using location as a cue to direct attention. Both automatic and attention-driven processes thus influence stream formation (ibid).

3.2.1.2. Posner and Rothbart's model of attention, self-regulation and consciousness

Posner and Rothbart (1998) introduced a model in which executive attention is used to control details of our awareness. Tthe authors favor a view of EF in which an integrated network of brain areas is involved. The focus of the model is to provide an approach to examine EF as a developmental process in early childhood and to link individual differences in EF to the maturation of underlying neural systems. To this end, Posner and Rothbart (1998) conducted experimental work to reveal conflict resolution skills in children as young as 18 months, possibly reflecting neural development in frontal midline areas.

3.2.1.3. Norman and Shallice's Attention to Action model

Norman and Shallice (1986) focused on understanding the role of attention in the control of action, especially when that action is under conscious control– both in cases of external and of internal actions. The model focuses on how executive attention works in adults, but it does not handle the development of these abilities. The authors put some emphasis on the way that conscious control can be used to enhance wanted actions as well as to suppress unwanted actions, which could be seen as an aspect of selective attention.

The model has one basic mechanism, which acts through activation and inhibition of supporting and conflicting schemas, which Norman and Shallice (1986) coined *contention scheduling*. With increased mastery of a specific task, the schemas could become more specialized, thus reducing interference and minimizing the need for inhibition among several schemas. The model also includes the Supervisory Attentional System (SAS), which provides control upon the selection of schemas and which is placed in the prefrontal cortex, in other words a specified executive functioning module. The model implies that well-learned cognitive skills and procedures do not require higher-level control and that an individual is more distractible when several schemas have similar activation levels.

Norman and Shallice (1986) claimed that there was ample neuropsychological evidence to support their theory, mainly the analysis of difficulties in patients with frontal lesions. Nevertheless, the model was modified by Shallice and Burgess (1996), who argued for a set of subsystems of SAS in prefrontal cortex. These subsystems were suggested to implement different processes, corresponding to subcomponents of EF (ibid.).

3.2.1.4. Barkley's model of behavioral inhibition, sustained attention and executive functions

Barkley (1997b) formulated a model focusing on ADHD, in which behavioral inhibition permits proficient performance with regard to working memory, self-regulation of affect-motivation-arousal, internalization of speech and behavioral analysis and synthesis, also referred to as reconstitution. In other words, inhibition is seen as superordinate in relation to other EFs, and this inhibitory capacity consists of several processes, including interference suppression. In this view, each of these executive functions represents a semi-independent system that interacts with the other executive functions in producing self-regulation (ibid.). Barkley (1997a) furthermore claimed that there must exist some mental faculty that allows the individual to organize behavior across time delays and to delay gratification. This faculty needs the capacity to recall and analyze sequential chains of events to be able to construct hypothetical futures. Considering the often-reported associations between EF and language (see also Section 3.3 below), and the high comorbidity of ADHD and language disorder (e.g. Bruce et al., 2006; Miniscalco et al., 2018; Mueller & Tomblin, 2012; Redmond, 2016), it is worth pointing out that internal speech is included as an executive function in Barkley's model. Language is here referred to not only as a means for communication with others but also as a way of communicating with the self. Internal speech could for instance take the form of self-directed instructions, thereby constituting an important tool for self-control. Barkley (1997b) also refers to self-directed/internal speech as a means of formulating rules and plans, including metarules that can be generated into a hierarchical system (cf. the Iterative Reprocessing model, Zelazo, 2015; Section 3.2.1.7 below).

3.2.1.5. Baddeley and Hitch's Central Executive

Other models have focused on the EF component working memory, such as the well-known model by Baddeley and Hitch (1974). The original version had three major components: the central executive, described as a central control system without intrinsic storage capacity, which is aided by two subsidiary slave systems – the phonological loop and the visuo-spatial sketchpad. An additional component was later added to the model, namely the episodic buffer (Baddeley, 2000), since the original model could not account for integration of information in different modalities or serial recall. This buffer is assumed to be capable of drawing information from both the phonological loop, the visuo-spatial sketchpad and long-term memory (ibid.). Alloway, Gathercole, Willis, & Adams (2004) assessed phonological short-term memory, complex memory span and sentence repetition in a sample of over 600 English children aged 4–6, conducted confirmatory factor analysis and found the strongest support for a model of separate factors corresponding to the phonological loop, the central executive and the episodic buffer.

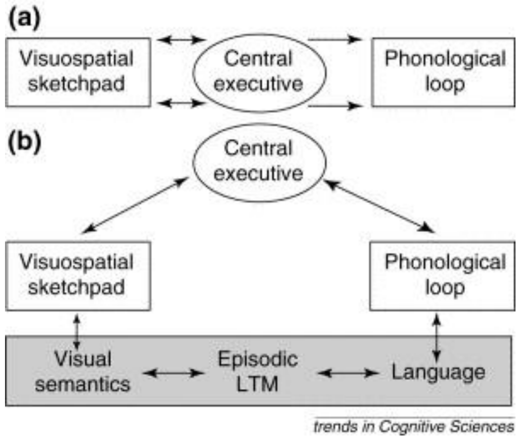

Figure 2. Baddeley and Hitch's model of working memory, including the episodic buffer. Reprinted from Trends in Cognitive Sciences *4(11), Baddeley, A. The episodic buffer: a new component of working memory? Copyright (2000), with permission from Elsevier.*

3.2.1.6. Cowan's model of working memory and selective attention

Cowan (1988) suggested a different working memory model, in which the content of working memory, or in Cowan's words, "short-term storage", is merely the sum of all activated information. By this definition, items are not "in" or "out" of working memory, but can rather be described as more or less activated. Although there may be modality-specific components in the second phase of sensory storage, Cowan emphasized that the common features, regardless of modality, are most important when attempting to understand the processing system. Cowan's model also includes a central executive or central processor, which here refers to all types of information processing that is under voluntary control. Cowan's theoretical framework includes some specific ideas about selective attention, including the habituation hypotheses of selective attention. If selective attention worked like a physical filter that shuts out unattended stimuli, how come it is easy to detect a change in an unattended channel? Instead of a filtering out or attenuating information on a physical basis, the system may rather develop a description of the irrelevant stimuli in memory, which would result in habituation to those stimuli and would then inhibit further processing of stimuli that fit this description. For instance, if a dichotic listening experiment has one female and one male voice and the participant is instructed to attend to the female voice, the information processing system may develop a description of the particular male voice that he/she is supposed to ignore. With regard to the mechanisms of selective attention, Cowan emphasized the need for specifying which sensations, coding processes or perceptual inferences are influenced by selective attention. He reviewed the evidence regarding selective attention, for instance the classic dichotic listening study by Hillyard, Hink, Schwent, and Picton (1973), which showed that event-related potentials to attended versus unattended stimuli diverged after only 50 ms. Evidence for this early, automatic processing does not however, in Cowan's view, provide sufficient support to claim that all perception is carried out automatically. He further stated that the amount of automatic processing that occurs may depend on how familiar the subject is with the stimulus materials.

3.2.1.7. Zelazo's Iterative Reprocessing (IR) model

Zelazo's IR model defines EF as neurocognitive skills that are necessary for top-down, goal-directed modulation of attention and behavior and wants to avoid a conceptualization of EF as a homuncular ability, a modular system or a specific unit in the brain (Zelazo, 2015; Zelazo et al., 2003). The neurocognitive skills that constitute EF are in turn described as ways of using attention that are dependent on regions in prefrontal cortex as well as other areas. Zelazo agrees with the general idea that EF is assessed as cognitive flexibility, working memory, and inhibition (Diamond, 2013; Miyake et al., 2000). These EF skills manifest as overt behavior reflecting goal-directed modulation of attention and are made possible by reflection, defined as reprocessing of information. The iterative reprocessing of information permits formulation of increasingly complex rules that are used for self-regulatory purposes.

> Reflection allows for the ad hoc construction of more complex representations, as measured by the hierarchical complexity of the rule systems that can be formulated and maintained in working memory. (Zelazo, 2015).

Increased efficiency of reflection is a result of reflecting in the context of problem-solving, which in turn allows for more efficient problem construal, and makes possible increasingly complex rules that children can formulate and keep in mind (ibid.). In Zelazo's (2015) view, the use of language then facilitates goal-directed control of attention flexibly and selectively over time. In other words, EFs are verbally mediated. Doebel and Zelazo (2015) conducted a meta-analysis of the well-used EF test *the Dimensional Change Card Sort* task (DCCS, see also Section 5.3.1 below), targeting cognitive flexibility. Children's performance on DCCS could be improved by labeling test items or by verbally emphasizing conflict between sorting rules, thus providing support for the idea that EF performance can be enhanced by using language in certain ways.

3.2.1.8. Jacques' account of labeling and abstraction in the development of cognitive flexibility

Jacques (2001) limited her theory to cognitive flexibility but is worth mentioning since she presented specific ideas regarding the mediating role of language for EF development. These suggestions are to some extent similar to Zelazo's ideas of EF as verbally mediated, but Jacques emphasized in particular the arbitrary nature of linguistic symbols. In her view it is precisely the arbitrariness of linguistic symbols that makes it possible for language users to separate themselves from the immediate environment. The linguistic symbols create psychological distance between the language user and the external stimuli that those symbols represent (Jacques, 2001; Jacques & Zelazo, 2005).

3.2.1.9. D'Esposito's neural model of working memory

D'Esposito (2007) focused on working memory and in his view, the concepts of verbal and visuo-spatial storage buffers in the model by Baddeley and Hitch (1974) would suggest that there are specific parts of the brain dedicated to such storage, similar to a computer's RAM. However, when neuroimaging data are taken into account, there rather seems to be a network of brain regions that is critical for active maintenance of internal representation; working memory may be conceived of as an emergent property of functional interactions between prefrontal cortex and other parts of the brain rather than a fixed capacity (D'Esposito, 2007). Furthermore, active maintenance seems to involve the same neural circuits that represents the information itself (ibid.). Functional magnetic resonance imaging data suggest that verbal working memory can be conceptualized as involving activation of all cortical language representations, regardless of whether those representations are phonological, lexical or semantic (D'Esposito, 2007; Fiebach, Rissman, & D'Esposito, 2006), thus calling into question Baddeley and Hitch's (1974) phonological loop.

3.3. Psycholinguistic findings and EF

The Chomskian revolution promoted language as an entity that could be studied independently of its purpose, but since then cognitive psychology has had a profound impact on psycholinguistic research (see Altmann, 2001, for a review), meaning that domain-general cognitive mechanisms, including attention, inhibition and working memory, have been related to specified aspects of language processing, such as speech processing, lexical access, syntactic parsing, and discourse-level comprehension and production.

Attention in a broad sense has been shown to be closely related to language skills, and the integration of (visual) attentional and grammatical information has been suggested to limit the degrees of freedom on what a function of certain linguistic constructions might be (*the attention-grammar interface;* Ibbotson, Lieven, & Tomasello, 2013). Findings regarding connections between EF components and language include that non-verbal working memory seems to be closely related to language measures in atypical populations, such as children with developmental language disorder (DLD) or autism spectrum disorder, whereas results regarding typically-developing children are more ambiguous (see Ibbotson, 2020, for a summary), giving rise to the possibility of differentiated patterns of language–EF associations in impaired versus non-impaired groups. With regard to inhibition, it has been suggested that the inhibitory mechanisms involved in language processing may in fact not be domain-general, but rather specific for language (e.g. Borragan et al., 2018). There could be a difference between conscious, higher-order aspects of "true" EF, as opposed to more basic processes of inhibition or working memory, the latter which may be functionally inseparable from language processing (see also MacDonald & Christiansen, 2002). Recent advances also include neuroimaging studies of narrative, and results thereof reinforce the idea that narrative is characterized by interaction of language and other cognitive mechanisms, for instance networks dealing with mentalizing abilities (e.g. Abdul-Sabur et al, 2014).

3.4. The language–EF relationship

The development of language skills and EF could to some extent be overlapping processes, and concurrent as well as longitudinal relationships between language and EF during childhood have been reported in a plethora of studies, some of which will be reviewed in the coming sections. The present work will not provide clarification of the *direction* of the language–EF relationship, since longitudinal data are not available. Rather, I attempt to contribute to increased understanding of the *nature* of the relationship between language and EF.

On one hand, research has indicated that aspects of EF seem to lay the foundation for early language development, based on the assumption that good EF facilitates language learning. On the other hand, language has been claimed to have a crucial role in the development of EF, a view based on theoretical accounts of language being used to regulate and reflect on goal-directed behaviors, that language may afford children to think in ways that advance cognitive development, or that EFs are verbally mediated. Furthermore, individuals with relatively selectively impaired language capacities (DLD, formerly referred to as specific language impairment, SLI) often display low performance with regard to executive functions, albeit not fulfilling diagnostic criteria for conditions such as ADHD or autism spectrum disorder.

3.4.1. General models

As a vantage point for further discussion about the nature of the relationship between language and EF, three possible and very general models of the relationship between language ability and EF are considered, inspired by Bishop, Nation and Patterson (2014), who discussed the nature of the language–EF relationship in the context of impaired abilities. It should be noted that some of the seemingly contradictory findings regarding associations between language and EF stem from different ways of operationalizing and assessing the abilities as well as lack of consensus in definitions of language and EF in themselves.

A. EF affects language functioning
B. Language functioning affects EF
C. A third factor, X, influences both EF and language

Model A can be taken in two ways. On a superficial level, EF may act as a confounding factor, if a language task includes high executive demands (task impurity, see also Section 4.1.2). Alternatively, there may be a deep link between EF and language as suggested by Mirman and Britt (2014), who claimed that language problems may be the result of access deficits, in turn based on problems with inhibitory control, activation and/or selection, thus indicating that EF may be intrinsically involved in language function. Novick, Trueswell and Thompson-Schill (2005) emphasized the importance of general cognitive control mechanisms for sentence parsing and stated that the left inferior frontal gyrus, including Broca's area, is part of a network that detects and resolves incompatible stimulus representations. The left inferior frontal gyrus is thought to reanalyze the input in the face of misinterpretation. However, it can be questioned whether these mechanisms are truly EF, in the sense of conscious cognitive control.

In support of Model B, as suggested by Hauser, Chomsky and Fitch (2002), so-called non-verbal aspects of cognition may be influenced by linguistically-based thought processes. Model B would thus be compatible with a domain-specific, generativist view of language. In line with a perspective that language affects EF, but which does not explicitly formulate a theory regarding the nature of language, are the ideas put forward by Zelazo and colleagues (e.g. Zelazo & Frye, 1998; Zelazo et al., 2003), arguing that children's language is a fundamental precursor to the development of EF. In this perspective, language enables the children to form a mental representation of the problem or conflict to be solved. Language is also needed to construct and use embedded rule structures that help children to solve a given problem. Rule representations are verbally mediated in that they are represented internally via self-directed speech in working memory, according to Zelazo (2015). Jacques' ideas about the crucial element of linguistic arbitrariness to create psychological distance between symbols and the stimuli that those symbols represent would also fit with Model B (Jacques, 2001, Jacques & Zelazo, 2005).

Model C suggests that difficulties with language and EF co-occur because they are influenced by the same causal factors, perhaps a domain-general cognitive capacity such as declarative memory, as suggested by Sundqvist, Nordqvist, Koch, and Heimann (2016), intelligence or processing speed. Work pointing to a common underlying ability for language and communication as well as for EF includes studies which have investigated links between early communication skills, such as the use of gesture, and aspects of EF and social cognition. However, Model C does not provide a satisfactory account of why some aspects of language predict later EF and vice versa.

3.4.1.1. A. EF predicts language

Several previous studies have found that EF predict language from an early age and up to preschool years, and the current account will provide some examples (see also Table 1).

A potentially important way that language and EF may be intertwined during early development is the ability to tune in to relevant aspects of the social and linguistic environment, in other words aspects of attention. Failure to allocate attention appropriately would lead the child to miss important cues, which in turn would affect their language acquisition. The process by which the caregiver uses eye contact and gaze to direct their child's attention to a specific object or event requires the child to orient toward the linguistic input, shift the attentional focus between visual stimuli and integrate information from various sources, potentially in several modalities (D'Souza, D'Souza, & Karmiloff-Smith, 2017). In this way, attention may be a part of EF that heavily influences language acquisition

Rose, Feldman, and Jankowski (2009) found concurrent relationships between cross-modal transfer, which could be interpreted as an aspect of the EF component shifting, and parent-reported productive and receptive vocabulary at age 1 as well as predictive relationships between cross-modal transfer and receptive vocabulary and verbal fluency, both measured with behavioral tests, at age 3. Weiland, Barata, and Yoshikawa (2014) examined 400 preschool-aged children and found that EF skills at the beginning of preschool were a significant predictor of receptive vocabulary skills at the end of preschool, controlling for receptive vocabulary at the beginning of preschool. However, receptive vocabulary at the beginning of preschool did not predict EF at the end of preschool, controlling for EF at the beginning of preschool. Woodard, Pozzan, and Trueswell (2016) showed that individual differences in children's EF were related to the ability to interpret temporarily ambiguous sentences. A longitudinal study of 90 Dutch children in kindergarten showed that EF uniquely predicted phonological awareness (ten Braak et al., 2018). Recent empirical work concerning young children that can be interpreted in favor of Model A includes a study by Gandolfi and Viterbori (2020), who found longitudinal associations between inhibition and language; more particularly so between interference suppression and morphosyntactic skills. Intervention studies can provide further answers to the question if improvement in EF leads to gains in language functioning (see also Gooch, Thompson, Nash, Snowling, & Hulme, 2016).

Table 1. EFs predicting language skills. A selection of studies indicating that some aspect of EF predicted some aspect of language in preschool-aged and young school-aged children.

EF component	Language skill	Age group	Sample size	Reference
Cross-modal transfer/ shifting	Vocabulary; verbal fluency	1-year-olds; follow up at age 3	182	Rose et al., 2009
Working memory, shifting, inhibition	Receptive vocabulary	4-year-olds (fall and spring in preschool)	400	Weiland et al., 2014
Cognitive flexibility	Receptive language (ambiguous sentences)	4;0 - 5;9-year-olds (2 assessments 2 weeks apart)	40	Woodard et al., 2016
Inhibition	Lexical comprehension and production; Grammatical production	2;0 - 2:8-year-olds, follow up at 3;0 - 3;8 years of age	62	Gandolfi & Viterbori, 2020
Attention/inhibition	Narrative skills	4-5-year-olds	42	Friend & Bates, 2014
Attentional control, behavioral control	Phonological awareness	6-7-year-olds	80	ten Braak et al, 2018

1.1.1.1. B. Language predicts EF

There is also evidence indicating that language skills predict EFs in early childhood (see also Table 2). Language comprehension at 14 months related to EF performance at 18 months (Miller & Marcovitch, 2015). It has also been shown that communicative gesture at 15 months of age predicts EF at age 4, thus indicating that nonverbal aspects of communication in young children can work as early indicators of EF (Kuhn et al., 2014). In a study of 132 children aged 42–63 months, Fuhs and Day (2011) found that verbal ability was a significant predictor of longitudinal change in EF. A composite language score, consisting of receptive vocabulary and comprehension and production of grammar, predicted EF performance in German preschoolers better than vice versa (Slot & von Suchodoletz, 2017). Language has a mediating role in EF performance when comparing non-verbal EF skills in deaf and hearing children (Botting et al., 2017). Intervention targeting aspects of language can improve selective attention (Stevens et al., 2008) and language development may thus directly influence attentional processing, which has also been suggested by Petersen et al. (2013).

Table 2. Language skills predicting EFs. A selection of studies indicating that some aspect of language predicted some aspect of EF in preschool-aged children.

Language skill	EF component	Age group	Sample size	Reference
Language comprehension	Inhibition, cognitive flexibility	1;2 and 1;6 year-olds	47	Miller & Marcovitch (2015)
Communicative gesture, expressive and receptive language	Working memory, inhibition, shifting	1;3 - 5 years	1 117	Kuhn et al. (2014)
Receptive vocabulary, grmmar comprehension, grammar production	Inhibition, shifting, working memory	3-4 years	227	Slot & von Suchodoletz (2017)
Receptive and productive vocabulary, information	Inhibition, shifting	Fall/spring of preschool (4-5 years)	132	Fuhs & Day (2011)
Narrative ability	Attention/shifting	4-5 years	42	Friend & Bates (2014)

1.1.1.2. C. A common underlying factor

Another option would be to consider language and EF as the result of some common underlying domain-general cognitive ability. A small number of cognitive variables may explain substantial proportions of variance in a wide array of language skills as well as EF, and every language skill that has been systematically examined recruits general cognitive capacities (Deák, 2014). A possible underlying cognitive factor for both language and EF would be intelligence. It has even been suggested that language proficiency and intelligence are virtually equivalent (e.g. Oller, 1981), but this may be taking things a bit too far. Most would however agree that language and EF development are closely intertwined with other aspects of cognitive development.

More specific signs of some common underlying factor affecting both EF and language development is for instance that in early child language development, the onset of symbolic gesturing just before the naming burst does not seem to be coincidental and likely reflects a common underlying cognitive ability (see also Section 2.1 above). Early gesture use also correlates with measures of Theory of Mind, the latter which according to some could also be attributed to aspects of cognitive flexibility (Jacques & Zelazo, 2005) or to EF in a more general sense (e.g. Tomasello, 2018; Section 2.2). Findings by Kuhn and colleagues (2014) showed that individual differences in communicative gestures at 15 months predicted language development at 2 and 3 years, which in turn predicted EF at age 4. Early gesture use may represent this underlying cognitive ability, since it can predict language development and can also work as an early indicator of EF.

3.5. Mathematics, language and EF

As previously mentioned, mathematical ability shows associations to language as well as EF. Similar to both language and EF, aspects of parental input make profound contributions to children's development of mathematics by structuring the learning environment and directing children's attention to important aspects of specific contexts (Mix, Sandhofer, & Baroody, 2005).

In Piaget's classical account of mathematics development, mathematic learning happens by reflective abstraction, but it is action, not language, that plays the primary role in the formation of mathematics (Piaget, 1967; see also Nemati, 2019). Links between aspects of language and mathematics are however widely attested: Harvey and Miller (2017) found that receptive vocabulary accounted for variance in mathematics skills in preschool-aged American children. Mix, Sandhofer, and Baroody (2005) point to similarities in the processes of learning number concepts and of learning other concepts, in terms of noticing similarities, forming categories and pairing words with referents, indicative of domain-general processes. Bonifacci et al. (2016) concluded that verbal number sequence knowledge predicted later arithmetic ability in preschoolers. LeFevre and colleagues (2010) found support for a model in which language skills were related to number naming, whereas nonlinguistic arithmetic was associated with subitizing latency/quantitative knowledge, suggesting separate pathways which vary in importance depending on the task at hand, providing some explanation as to why children with DLD perform lower on mathematical tasks that have a linguistic component than on tasks where quantitative knowledge is most relevant. However, it has also been suggested that verbal and nonverbal components influence one another bidirectionally during number development. Such accounts also emphasize contextual aspects, for instance the importance of scaffolding, in line with a perspective on development as dynamic and multifaceted (e.g. Mix, Sandhofer, & Baroody, 2005, for a summary and discussion).

With regard to EF, succeeding at Piagetian number-conservation tasks seems to rely in part on the executive ability to solve the interference between relevant and irrelevant dimensions (Houdé et al., 2011). Harvey and Miller (2016) found specific associations between EF and mathematical abilities. Blair and Razza (2007) found that inhibitory control accounted for unique variance in mathematics ability in preschool and kindergarten and conclude that their results were consistent with an overlap in neural substrates for EF, numerical ability and quantitative reasoning. The connection between EF and math can be understood in terms of demands of the problem-solving process, in which one needs to represent information in working memory, shift attention between different elements of the problem and inhibit inappropriate responses (Blair & Razza, 2007; Cragg & Gilmore, 2014).

To conclude, mathematics, language and EF seem to overlap to some extent with regard to the cognitive and neural mechanisms that are involved in development. To solve mathematics tasks, children appear to recruit language and EF skills at a varying degree, depending on the nature of the task. Additionally, children's development of number sense is, as other aspects of cognitive development, influenced not only by factors within the individual but also by the environment, including aspects of parental input.

3.6. Concluding remarks

Previous studies regarding the language–EF relationship show diverging results with regard to the direction of the relationship as well as more specific associations between aspects such as vocabulary, morphosyntax and narrative skills and EF.

There are several challenges from a theoretical point of view in interpreting and understanding the language–EF relationship and furthermore to formulate a unified theory which can be empirically tested in future work. One of these challenges is the absence of consensus regarding definitions and theories describing the very nature of language and EF. A couple of the EF theories presented above include aspects of language, providing some basis for the language–EF association, but these theories seem underspecified with regard to the exact nature and direction of such a relationship. To further complicate the picture, it has also been suggested that some processes labeled as EF may in fact be language-specific. Another aspect that needs clarification is the role of selective attention for EF: Is selective attention, in the form of interference suppression, one of several sub-processes of inhibition, or is selective attention, in the form of orienting, the foundation for early EF? Yet another factor that needs further consideration is the role of selective attention for language (and potentially vice versa). Research which places language in the foreground has shown a tight relationship between grammar and attention in a broad sense, and empirical findings support the idea of a specific association between morphosyntax and inhibition in the form of interference suppression. But how do these abilities interact and are they functionally separable?

An emergent perspective on language acquisition goes hand in hand with a general view on development as dynamic and self-organizing, but closer specification is nevertheless required as to *why* aspects of language and EF would be connected and, above all, *how* the seemingly interdependent development of these aspects of cognitive ability takes place. On the other hand, a theoretical perspective in which language is seen as clearly separate from other parts of cognition, and the focus of interest is restricted to syntax, would certainly limit the number of options with regard to the hypothetical causes for a language–EF relationship. A view on development in which language is part of, not separate from, other cognitive abilities, potentially makes it more difficult to delineate which processes should be considered linguistic as opposed to related to EF. Clear definitions and operationalizations are therefore vital in any attempts to clarify the course and cause of development.

4. Methodological considerations

This chapter is structured as follows: I start with outlining some of the major challenges in assessing language and EF in a reliable way. After that, I present a selection of language and EF measures, both behavioral tests and indirect measures such as ratings or questionnaires, that are potentially suitable for use with preschool-aged children in the Swedish context. Next, I provide a more detailed description of what the event-related potential (ERP) technique entails before moving on to describing previous findings regarding selective auditory attention using the original version of the ERP paradigm employed in Study II and Study III. Brief sections follow on assessment of early mathematical ability and emotional comprehension in preschool-aged children, since math and emotional comprehension was included as one of the outcome measures in study III. The chapter concludes with a summary of the language and EF tests and tasks used in the four studies included in this thesis; see also Study III for additional information and references.

It should be noted that data collection for the studies included in this thesis took place in the spring of 2016 (Study I) and during fall 2016 and spring 2017 (Studies II–IV), entailing that some of the materials covered in the upcoming description were either not available at the time of data collection, or were not considered sufficiently evaluated to be the choice of method/material for the current work.

4.1. Challenges

Investigating the nature of the relationship between language and EF is not without challenges, on a theoretical level as well as from methodological and practical points of view. There is a principal difference between language and EF assessment. The latter tries to capture some latent variable(s) and can thus be more opaque in what is actually being measured, whereas language tests are often more transparent and perhaps easier to interpret. Nevertheless, the generalizability of a specific language task result may be limited, since language use differs according to the context (for instance elicited speech versus spontaneous speech or dialogic conversation versus monologic narrative). The opacity of EF tests holds in particular for computerized assessment (Gershon et al., 2013; see also Section 4.3.1 below).

The main problems in assessing language and EF in conjunction can be summarized as: 1) conceptual confusion, 2) the task impurity problem, 3) trade-offs and practical limitations, 4) problems with validity and reliability, and 5) shortage of suitable test materials.

4.1.1. Conceptual confusion

Our choice of methods to assess language and EF may be obscured by conceptual confusion concerning what EF really is, whether aspects of language should be considered part of, or a basis for EF, and, conversely, whether aspects of EFs are foundational for language development or if cognitive control could be regarded as an intrinsic part of language processing. For instance, as stated in Section 3.2, there are theories of EF which regard internalized speech as an executive function (Barkley, 1997b) as well as theories of EF in which language is a prerequisite for the development of efficient EF (e.g. Zelazo, 2015). These particular theories form the basis of quite similar ideas regarding the role of language in EF and/or self-regulatory behavior, enabling reflection and the formation of hierarchical rules, and would logically lead to hypotheses regarding specific associations between syntactic complexity and EF. However, if one considers inhibition as underlying language processing, or if one views attention capacities as a general constraint on language acquisition, this leads to diametrically different predictions and research designs (see e.g. D'Souza, D'Souza, & Karmiloff-Smith, 2017; Gandolfi & Viterbori, 2020). For EF, there are also challenges with regard to definitions and terminology, for instance 'short-term memory' and 'working memory' are sometimes used interchangeably and ambiguously (see Aben et al., 2012, for a critical review and discussion).

Additionally, measures of language investigated in conjunction with EF have often been limited to aspects of vocabulary. As stated by McKean and colleagues (2015), although such measures are often highly correlated with other language abilities, the developmental trajectory of, for instance, receptive vocabulary may not be representative of growth in syntax and morphology, since optimal periods are not identical for different language components. Furthermore, results regarding the dimensionality of language at different ages are diverging (see Section 2.2.1 above) and it is thus inadequate to let vocabulary measures represent language as a whole.

Taken together, these factors also lead to difficulties in interpreting results, not least when one wants to compare EF outcomes from different studies (Fuhs & Day, 2011). Even if there was complete agreement regarding the definition of EF and EF tasks, some tasks will inevitably require the involvement of more than one of the core EF components. For instance, to succeed at tasks assessing cognitive flexibility requires that one can keep at least two rules in working memory but also that one has the ability to inhibit previously engaged responses (e.g. Davidson et al., 2006; Dajani & Uddin, 2015, Doebel & Zelazo, 2015).

4.1.2. The task impurity problem

> A pervasive but seldom acknowledged problem is that most executive function tasks recruit language skills. (Déak, 2014, p. 287)

It is nearly impossible to obtain a pure behavioral measure of EF, since language and motor skills are needed to complete the assessment tasks. There is a general problem with task impurity when collecting both language and EF data and it can be hard to separate for instance problems with comprehension of complex syntax from limitations in working memory. Language-processing demands as a confound in EF assessment have not been sufficiently problematized in the literature (see also Déak, 2014, Ibbotson, 2020; Kaushanskaya, Park, Gangopadhyay, Davidson, & Weismer, 2017). For instance, it is very rarely mentioned whether or not children's vocabulary is controlled for when conducting different word span or verbal fluency tasks. The latter is traditionally described as a good indicator of overall cognitive activation (e.g. Lezak, 2012), but, at least in adults, verbal fluency performance has been shown to be related both to EF and to vocabulary size (Shao et al., 2014), or relating more to language than to EF (e.g. Whiteside et al., 2016). Furthermore, it has been suggested that verbal working memory is not functionally separate from linguistic knowledge (McDonald & Christiansen, 2002). Cognitive flexibility tasks often require good comprehension of embedded clauses but any attempts to control for this experimentally or statistically seem scarce and moreover, researchers rarely comment on the potential problems with using test tasks that are linguistically demanding. At most, there are claims that verbal demands were low, since children did not need to give a verbal response, but considerations regarding children's language comprehension demands seem largely non-existent.

Task impurity may pose an even larger dilemma in auditory selective attention tasks employing linguistic materials as stimuli. Whereas the ecological validity can be considered higher in paradigms trying to create more natural listening scenarios rather than focusing on subtle acoustic differences (see also Shinn-Cunningham & Best, 2015), the potential downside is that it becomes difficult to control exactly what is being measured.

Conversely, language tests may pose high demands on EF, and some tests that are primarily considered language tasks, such as the Peabody Picture Vocabulary Test (PPVT, Dunn & Dunn, 2007), are sometimes used as a proxy for general intelligence or verbal IQ, further complicating interpretation of results regarding the language–EF relationship (see for instance Blain-Brière, Bouchard, & Bigras, 2014; Bornstein & Putnick, 2012; Lopez Boo, 2016; NICHD Network, 2003). It has also been acknowledged that individual variation in test administration may have large effects on children's results (e.g. Haake, Hansson, Gulz, Schötz, & Sahlén, 2014), emphasizing the need of standardized procedures, for instance computerized versions of existing assessment materials.

4.1.3. Trade-offs

A thorough investigation of cognitive skills in young children needs to balance the ambition to get a representative picture of the skill(s) of interest and practical aspects such as limited resources and time constraints. To get a fair picture of an individual's language capacities, several sources of information are needed. It is rarely sufficient to administer a single test or a couple of tests, but samples of naturalistic language are needed for an ecologically valid assessment. This presents a practical problem both in research and in clinical or educational settings: Assessment can be very time-consuming, tiresome for the child and resource-demanding for the examiner. Neither is it sufficient to let one or two EF tests/tasks represent the entire EF capacity, as long as the latent structure of EF is disputed and may depend heavily on the choice of particular tasks and performance indicators (e.g. Miller, Giesbrecht, Müller, McInerney, & Kerns, 2012). Lengthy and more or less tiresome test sessions with young children could be described as unethical. Children seldom have full agency to choose whether or not they want to participate in research; the potential benefits of future results may be unclear to them and the novel situation may be intimidating. The challenge is thus to collect a sufficient amount of data on both language and EF that will allow for far-reaching conclusions about the nature of the relationship, without exposing the participants to unnecessary or tedious procedures.

Potential subcomponents of language may be differentially related to submeasures of EF. If one selects one or a few aspects of language, for instance receptive vocabulary, represented by a single test result, and investigate how it is associated with EF, it is vital to not overgeneralize those results as pertaining to 'language' as a whole.

Relevant information regarding children's language and EF capacities can be obtained in several ways and behavioral tests could be complemented by questionnaires and ratings by teachers and parents. Yet another possibility is to complement or to some extent replace performance-based assessment with electrophysiological measures such as ERP and/or neuroimaging, which can enhance our knowledge about the neural basis of language and EF, but which demand a lot of resources and require further ethical considerations. There is also a need for basic research regarding how language and EF capacities are reflected in ERP, since the associations between behavioral assessment and ERP can be rather weak (e.g. Häger et al., 2020).

4.1.4. Reliability and validity

A principal problem with measurement of cognitive skills in general is that in research, we are often interested in results or effects at a group level, whereas in assessment for clinical or educational purposes the focus is on individual differences and intervention. Experimental tasks that are reliable at the group level often exhibit low test/retest reliability since they aim to minimize between participant variability and are thus unreliable to measure individual differences (e.g. Hedge, Powell, & Sumner, 2018; Kidd et al., 2018). Additionally, in a context such as Sweden, there is a general shortage of test materials that are linguistically and culturally adapted and that have been examined with respect to reliability and validity.

Very few EF measures that are suitable for preschoolers have undergone analyses of test-retest reliability (Carlson et al., 2016). Among the exceptions we find computerized EF tests included in the NIH Toolbox battery, which have been validated on approximately 85 American children aged 3 to 6 and found to be reliable and valid and suggested to be suitable for intervention studies (Zelazo et al., 2013). It should be pointed out that the validation sample was rather small. A couple of tasks from the NIH Toolbox were employed in the current studies (see Section 4.3.1 below).

There are concerns that experimental EF tasks may lack in ecological validity, and it has therefore been recommended that performance-based EF assessment should be complemented by parental and/or teacher reports. However, correlations between directly assessed EF and assessment via questionnaires tend to be modest or low. Toplak, West, and Stanovich (2013) reviewed 20 studies using performance-based and rating measures of EF and concluded that these measures seem to assess different underlying constructs. The authors suggested that performance-based measures give an indication of optimal capacity, whereas rating measures reflect typical EF capacity (ibid.). A similar conclusion was recently reached by Häger et al. (2020), who found rather weak associations between EF test results, ratings and ERP components in Norwegian children and adolescents with ADHD and suggested that different measurement methods may correspond to different levels of the phenomenon of interest. Lack of significant correlations between EF assessed with behavioral methods and EF/selective auditory attention, measured with ERP, is thus not necessarily a problem. Nevertheless, Häger and colleagues (2020) state that more basic research is needed on how ERPs manifest EF function at different stages of development and how they relate to other measures of EF.

Some work has been done during later years to establish whether ERP show test-retest reliability, but considering how widely used ERP measures are in research, studies examining the reliability of such measures are relatively scarce (see also Huffmeijer, Bakermans-Kranenburg, Alink, & van Ijzendoorn, 2014). Walhovd and Fjell (2002) investigated one-year test-retest reliability of auditory ERP recorded in an oddball task in a sample of adults (aged 21–92) and found that amplitude measures were more reliable than latency measures at all electrode sites. Cassidy, Robertson, and O'Connell (2012) investigated several ERP components, including visually evoked P1, N100, P3a and P3b, the latter two being associated with attention resource allocation, in a sample of young adults and concluded that test-retest reliability was strong at one-month follow up. Peak amplitude was more stable than mean amplitude for shorter latency components such as P1 and N100.

4.1.5. Shortage of suitable test materials

With regard to the Swedish context, there is a general shortage of language and EF tests that cover the age range 4–6, are linguistically and culturally adapted, have any form of validation, norms or standard scores and that are sensitive enough to capture short-term developmental change. The design of test materials may reflect underlying, tacit assumptions regarding the nature of language and/or EF that may not have sufficient empirical support, for instance language tests that separate vocabulary and grammar into separate subscales, although language is possibly best characterized as unidimensional in early childhood (see Section 2.2.1.1 above), or EF tests which are claimed to tap into one specific EF component, although the latent structure of EF in early childhood is contested (Section 2.3.1).

4.2. Language assessment

Language assessment, in particular from a clinical point of view, is usually based on a detailed description of the child's skills within the different linguistic domains, using both formal instruments when available and informal, qualitative checklists or observations, also referred to as the 'developmental-descriptive model' (Paul & Norbury, 2012).

In the following section, I provide a summary regarding some of the test materials that are available in Swedish (although rarely with extensive and/or representative Swedish norms) and motivate the choice of materials for the studies included in the thesis. An overview of language tests and materials, including the extracted language measures reported in the current studies, is found in Table 3.

4.2.1. Language tests

4.2.1.1. Vocabulary

An instrument widely used in research as well as for clinical purposes is the *Peabody Picture Vocabulary Test* (PPVT, Dunn & Dunn, 2007), assessing receptive vocabulary. In its original version, the test is suitable from toddlerhood and all the way up to the geriatric population. However, there are no official Swedish translations or published Swedish norms. Unofficial translations, used both in Swedish child language research and in speech-language pathology, have neither considered the rising level of difficulty that is present in the original version of the PPVT nor considered potential needs for adaptations of the picture plates and results need therefore be interpreted with caution. An attempt to ensure a rising level of difficulty was made by Karner and Mattsin (2017), who included school-aged children in their study, but the updated translation was not available at the point of data collection for the studies included in this thesis.

Crosslinguistic lexical tasks (CLT; Haman, Łuniewska, & Pomiechowska, 2015) have been designed for use across different languages and thereby also valid for use with bi- or multilingual participants. In 2017, Haman and colleagues published a paper with data on vocabulary size acquired via a crosslinguistic lexical task administered to 639 children aged 3;0–6;11 across 17 languages. Had CLT been available at the point in time when our data collection started, it might have been the preferred choice, since the samples for the current studies were linguistically very diverse. Since then, CLT have also been used in research regarding Swedish mono- and bilingual children with typical and atypical language development, to some extent providing some normative data (e.g. Öberg, 2020).

4.2.1.2. Grammar

Test of Receptive Grammar (TROG-2, Bishop, 2003) assesses comprehension of grammatical contrasts and has Swedish norms available for children aged 4;0–12;11. *The Grammar test for children* (Gramba; Hansson & Nettelbladt, 2010) is a Swedish test that, according to the manual, assesses production of all grammatical constructions that are of importance for a child's grammar development; however the test taps more into morphology than syntax. Gramba norms are available for children aged 3–6. Both TROG-2 and Gramba would thus be suitable for 4–6-year-olds, the age group of interest for this thesis. However, both tests have a rather limited scope since they address aspects of grammar skills only. For Gramba in particular, there may be training effects when using the instrument twice in a short time period, which would make it additionally less suitable for intervention research.

4.2.1.3. Pragmatics

It is recommended that assessment of pragmatic ability in young children, at least for clinical purposes, should focus on elicitation of communicative intent via naturalistic methods, and, as children grow older, the assessment should also include investigation of speech acts, conversational and narrative abilities, understanding of implicature and the child's ability to use contextual cues to understanding (e.g. Adams, 2002). The *Clinical Evaluation of Language Fundamentals* (CELF-4; Semel, Wig, & Secord, 2003) includes some aspects relating to pragmatics, but does not have a true pragmatic subscale or index. Various systems are available to code naturalistic interaction (see Adams, 2002, for an overview) but for the current studies a novel rating instrument of non-verbal communication was employed, see Section 4.2.2. below.

4.2.1.4. Comprehensive language test batteries

Only a couple of test batteries covering several aspects of linguistic ability are available in Swedish, including Swedish or Scandinavian norms. *The New Reynell Developmental Language Scales*, with Swedish norms for 2–7-year-old children, assesses comprehension and production of language with a focus on morphology and syntax (Lundeborg Hammarström, Kjellmer, & Hansson, 2017), but was released after data collection for the studies included in this thesis. CELF-4 (Semel et al., 2003) covers the age range 5–12 years, has been widely used in research internationally and includes indices for basic language skills, receptive language, expressive language, language content, language structure, verbal memory and working memory. It should be pointed out that the norm population was Scandinavian, not Swedish. Since CELF-4 is suitable from age 5, there is a risk of floor effects when using the battery at younger ages. There are also indications that the receptive index of CELF-4 may capture domain-general working memory ability (Kaushanskaya et al., 2017), in other words a potential task impurity problem.

4.2.1.5. Narrative assessment

To assess children's communicative competence using different narrative tasks is claimed to be ecologically valid (e.g. Botting, 2002), and to collect narratives is an efficient way to gather ample linguistic data. In terms of language assessment, narratives provide rich information concerning form, content, and use of language with little risk of ceiling effects even when collecting data from children of various ages, since narrative abilities and other discourse-level skills are prolonged developmental processes that continue to develop in adolescence and even adulthood (e.g. Aksu-Koç & Tekdemir, 2004; Karmiloff-Smith, 1985, see also Section 2.2.3 above).

Research from various settings have revealed cross-cultural variation in narrative conventions (e.g. Asplund Carlsson et al., 2001; Strömqvist & Verhoeven, 2004), meaning that results from one linguistic and cultural context cannot readily be generalized. It also means that researchers need to reflect upon the choice of story elicitation materials.

A narrative can be treated as a language sample with no specific interest in the specific narrative structure, which is the main approach for the studies included in this thesis. Measures such as lexical diversity, total number of words, number of communication units or unified predicates and syntactic complexity can be extracted from the narrative. One needs to be aware of the fact that language use varies according to context, including the linguistic context, meaning that for instance a child's level of syntactic complexity in narrative does not have to be representative of the child's grammar in everyday conversation. A narrative can also be examined with a focus on the specificities of narrative language, such as narrative coherence/story grammar, or zooming in on linguistic cohesion, such as the use of anaphoric and connective devices, important in both narrative and non-narrative discourse (see e.g. Karmiloff-Smith, 1985).

Different narrative tasks pose diverse demands on children and to obtain a complete picture of a child's narrative abilities, a variety of tasks should optimally be used. When it comes to collecting children's narratives, elicited tasks are often easier to administer and analyze compared to spontaneous story generation (Adams, 2002; Merrit & Lyles, 1989), meaning that when gathering children's narratives for research or clinical purposes, some kind of elicitation material is often used for convenience but also to enable comparisons over time or between groups of children. There are mainly two types of elicited narratives: Either the child retells a story he/she just heard, which is the case in the *Bus Story Test* (e.g. Renfrew, 1995) or he/she generates a story aided by pictures or other forms of visual material, such as wordless picture books, for instance the different versions of the Frog Story books (e.g. Berman, Slobin, & Aksu-Koç, 1994; Mayer, 1969; Strömqvist & Verhoeven, 2004), picture sequences such as *LITMUS-MAIN* (e.g. Gagarina et al., 2012) or the *Edmonton Narrative Norms Instrument* – ENNI (Schneider, Dubé, & Hayward, 2005). To retell or paraphrase a story is a memory task as well as a language task, which involves simultaneous processing of multiple levels of linguistic knowledge, cognitive organization and EF. To remember a story also requires the activation of concepts and schemas outside the realm of immediate short-term memory in order to process and recall the material (e.g. Gabig, 2008). Schneider and Dubé (2005) claimed that children may include more information when they retell a story than when the story is elicited by pictures and the child is not given a model. Support for this claim from the Nordic context is found in a study including Finnish and Finnish-Swedish-speaking 5–6-year-old children, revealing that story retell rendered stories with higher structural complexity and more internal state terms than tasks in which children generated their own story, regardless of language (Kunnari, Välimaa, & Laukkanen-Nevala, 2016). This may result from the fact that the child is provided with an exact verbal model. Formulating a story from scratch may however give a more representative picture of a child's genuine storytelling skills, such as narrative organization (e.g. Mäkinen, Loukusa, Gabbatore, & Kunnari, 2018).

In studies I, II and III, *The Bus Story Test* was used to elicit story retells. The material has been adapted for Swedish, with a manual guiding scoring procedure (Svensson & Tuominen-Eriksson, 2002) and is widely used in Sweden, clinically as well as in research on groups with atypical development (e.g. Johnels, Hagberg, Gillberg, & Miniscalco, 2013; Nordberg, Dahlgren Sandberg, & Miniscalco, 2015). The examiner first tells the story by using 12 cartoon pictures, with three pictures per page. The child is then asked to retell the story while he or she looks at the pictures. In studies II, III and IV, *Frog, Where Are You?* (Mayer, 1969) was used to elicit story generation. The child is instructed to first look through the picture book, while the examiner, if possible, appears to be preoccupied with test protocols. Then the child tells his/her story, aided by the pictures. For *The Bus Story Test*, the manual provides clear guidance how to calculate information score and a score of syntactic complexity. The latter measure could be readily applied to the frog story narratives, whereas information score for the frog stories used the event structure described in Berman (1988) as a vantage point to enable an equivalent scoring. Berman's measure of story length – unified predicates – was employed to both the story retell and the story generation and the well-used, more generic measures of lexical diversity and morphosyntactic accuracy were extracted from both types of narratives. See also Table 3.

4.2.2. Rating measures of language

4.2.2.1. Vocabulary

McArthur Bates Communicative Development Inventories (CDI) are available in a large number of languages. The Swedish versions cover the age range from 8 months to 4;0 years of age (SCDI, Berglund & Eriksson, 2000; Eriksson, 2000; 2017; Eriksson & Berglund, 1999), but needs to be used with caution in research in multilingual contexts and in cross-linguistic comparisons since the instrument was originally developed for a monolingual context and word lists differ quite substantially across the different adaptations (Bleses et al., 2008; Haman et al., 2017). Another limitation with SCDI is that it does not cover the entire preschool age range and it was not until after the data collection for the studies included in this thesis that a study on SCDI-III, designed for Swedish children from age 2;6 to 4;0, was published (Eriksson, 2017). However, by kind permission from Professor Mårten Eriksson, we were allowed to try the preliminary SCDI-III version that was available at the time of data collection for the current studies, which began in spring 2016. For Study IV, only the specific subscales regarding thought and emotion words are reported.

4.2.2.2. Grammar

The revised version of SCDI-III includes a subscale for syntax, including questions about language complexity and grammatical constructions. However, in the preliminary version used in the current studies, there were separate subscales for morphology and syntax respectively. A concern regarding parent ratings of grammar skills is that it may be more difficult for parents to correctly assess their child's abilities within this domain compared to vocabulary. The way statements are formulated in SCDI-III also requires good metalinguistic skills on the parent's side.

4.2.2.3. Pragmatics

The *Children's Communication Checklist,* version 2 (CCC-2, Bishop, 2012) is available in Swedish and suitable from age 4;0 to 16;11. CCC-2 is a questionnaire which renders a composite score of pragmatic language behavior. Among its assets are that CCC-2 is relatively quick to administer and that it can tap behaviors which are difficult to assess by sampling (see also Adams, 2002). In the current studies, parents were obliged to fill out extensive questionnaires regarding the child's medical history, family SES, preschool attendance etc. as well as a questionnaire regarding the child's strengths and difficulties (SDQ, see Section 5.2.2 below). No checklist regarding pragmatic language specifically was distributed to avoid the risk of overload for parents consenting to participate. Instead, a novel instrument was developed by Tove Nilsson Gerholm, based on Autism Diagnostic Observation Schedule (ADOS; Lord et al., 2000), which rated children's behaviors connected to interaction quality, based on video-recordings of the testing sessions, see also Table 3.

4.2.2.4. Comprehensive language questionnaires

Recent work by Visser-Bochane and colleagues (2020) indicates that language development in children aged 1–6 can be reliably measured with one, unidimensional scale that covers vocabulary, language and communication, in line with accounts of language as unidimensional in preschool ages, see Section 2.2.1.1. Authors conclude that their scale, although developed in Dutch, is likely to be useful also in other Germanic languages (ibid.).

4.3. Assessment of EF

EFs are not only elusive to define but also difficult to measure. The same task may be described as assessing different aspects of EF (e.g. Zelazo et al., 2003) and furthermore, the same task may tap different skills at different time points during development (Carlson, Faja, & Beck, 2016; Zelazo, 2015). To adequately describe the development of EF we need assessment materials that are developmentally sensitive (see also Carlson, 2005) but at the same time avoiding floor/ceiling effects. Clinically, combinations of direct assessment and parent/teacher ratings are often employed, and for research purposes, ERP are also used to index aspects of EF.

Correlations between different methods to assess EF tend to be modest or low, but researchers studying EF via combinations of parent ratings and performance-based measures have argued that both approaches are important, possibly capturing divergent but related information, but that they should not be used interchangeably (Loe, Chatav & Alduncin, 2015; Toplak et al., 2013). In spite of all the potential problems with measuring EF, it should be noted that many of the tasks and instruments used in young children still have a strong predictive value for social as well as academic success (e.g. Blair & Raver, 2015; Mischel, Shoda, & Rodriguez, 1989; Moffitt et al., 2011).

An overview of EF tests and questionnaires used in the current studies is found in Table 4.

4.3.1. EF tests

Assessment of EF in children has often been modelled on adult neuropsychological test batteries, leading to tasks that are not child-appropriate and which may produce floor/ceiling effects. During the latest two decades or so, efforts have been made to design suitable and developmentally sensitive EF measures for preschool-aged children and to validate those measures. This work has mainly been conducted in the United States (e.g. Cameron Ponitz et al., 2008; Espy, Bull, Martin, & Stroup, 2006; Gershon et al., 2013; Rueda et al., 2004; Tulsky et al., 2013; Weintraub et al., 2013; Willoughby, Blair, Wirth, & Greenberg, 2012; Zelazo et al., 2013). Exceptions include work by Mulder, Hoofs, Verhagen, van der Veen, and Leseman (2014), who investigated psychometric properties of an EF test battery for two-year old Dutch children and the development of an EF test battery for French-speaking Canadian children by Monette and Bigras (2008).

For Swedish, validated or norm-based EF tests for preschool-aged children are scarce. For school-aged children (7–14 years of age), the NIMES (*Neuropsychological assessment for the school-aged child*) has been translated from (Australian) English, has been used in research on EF in Swedish children and has, to some extent, been standardized for Swedish (e.g. Lindquist, Persson, Uverbrant, & Carlsson, 2008). The neuropsychological assessment battery NEPSY-II is available in Swedish and includes assessment of EF and attention, but only to a limited extent for preschool-aged children. There is a risk of potential confounding factors with some of the NEPSY EF subtests, such as the measure of cognitive flexibility also placing heavy demands on linguistic/semantic ability (Korkman, Kirk, & Kemp, 2011).

Subtests of NEPSY have been used in research on EF in Swedish, preschool-aged children (e.g. Brocki et al., 2010; Thorell et al., 2009), often in combination with adapted versions of EF tests and tasks that are widely used in research conducted in English-speaking contexts. Some of these tests have been further developed and standardized through extensive work with the NIH Toolbox computerized cognitive assessment battery (e.g. Weintraub et al., 2013). Included in the NIH Toolbox tasks for EF assessment are the *Dimensional Change Card Sort task* (DCCS), mainly assessing cognitive flexibility/shifting and the *Fish Flanker task*, mainly assessing inhibitory control in the context of selective visual attention. The former has been developed and extensively examined by Zelazo and colleagues (e.g. Doebel & Zelazo, 2015; Zelazo et al., 2013) and by Carlson (2005). The latter is a version of the original adult Flanker task, developed by Eriksen and Eriksen (1974), adapted for children (Rueda et al., 2004). While the NIH Toolbox tasks are validated and developmentally sensitive (at least for North-American children), the raw scores are rather difficult to interpret by themselves and it is hard to judge exactly what is being assessed without knowing the details about the algorithms computing the final result (but see Slotkin et al., 2012, for details).

Other well-used EF measures include word or digit span tasks, assessing short-term or working memory, depending on the design of the task (e.g. Pickering & Gathercole, 2001), and the *Head-Toes-Knees-and-Shoulders task*, developed by Cameron Ponitz and colleagues (2008) and described as an easy-to-administer behavioral regulation task which assesses behaviors similar to those required in the classroom, thus making the task potentially more ecologically valid.

4.3.2. Rating measures of EF

Instruments used to indirectly assess aspects of EF include the *Behavior Rating Inventory of Executive Function* – Preschool Version (BRIEF-P, Gioia, Andrews Espy & Isquith, 2003), suitable for children aged 2;0–5;11 and designed to evaluate children with learning difficulties, attention problems, brain injury, depression or other neurodevelopmental and medical conditions. The questionnaire contains statements within five clinical scales: inhibition, flexibility, emotional control, working memory and planning/organizing. Swedish norms are however not available.

Also available is the *Childhood Executive Functioning Inventory* (CHEXI), an instrument which focuses on EF without including items that overlap with the diagnostic criteria for ADHD (Thorell & Nyberg, 2008). The childhood version is freely available in 21 languages, is appropriate to use for parents, teachers or other persons that know the child well and is suitable for children from age 4.[2] CHEXI includes four subscales (working memory, planning, self-regulation and inhibition). For Swedish, a two-factor solution is verified: working memory and inhibition (Thorell & Nyberg, 2008). However, normative data are not available.

Yet another option is the *Strengths and Difficulties Questionnaire* (SDQ, e.g. Goodman, 1997; 2001; Malmberg, Rydell, & Smedje, 2003; Smedje, Broman, Hetta, & von Knorring, 1999), with freely available versions for parents and educators and suitable for children aged 2–17. The SDQ is recommended for use in clinical settings and in research, for instance to evaluate outcomes of specific interventions and is claimed to be well-adapted for studies on the general population (SDQ info, 2012), and was therefore administered to parents as well as teachers in the studies included in this thesis.

4.3.3. Event-related potentials

> The ERP technique allows us to observe a series of cognitive operations that take place from before the delivery of sensory information to the peripheral nervous system until even after a behavioral response is made. (Woodman, 2010, p. 2032)

One of the major advantages with ERP is the excellent temporal resolution, not least in relation to aspects of attention, which appears to operate on a scale of tens of milliseconds. ERP thus provide a direct measure of neurotransmission-mediated neural activity (see also Luck, 2014).

Compared to neuroimaging techniques, using EEG demands less resources and it is non-invasive. The participant wears a cap or a net with electrodes attached that measure the electrophysiological activity on the scalp. Another advantage of the method is that brain activity can be recorded also when the participant is not able to make a behavioral response, such as in young children or clinical populations. Unfavorable aspects of using ERP include that the methodology requires a large number of trials in an experiment to enable

[2] See also www.chexi.se.

meaningful interpretations (see also Beres, 2017). The poor spatial resolution is another potential drawback. In comparison with behavioral studies, the interpretation or ERP is less clear and even small differences between similar paradigms may lead to difficulties in comparing results.

In most experiments, an averaged ERP waveform is constructed at each electrode site for each subject in each condition. ERP components are usually defined by their polarity (positive or negative-going voltage), timing, scalp distribution and sensitivity to task manipulations. A suggested operational definition is provided below:

> An ERP component can be operationally defined as a set of voltage changes that are consistent with a single neural generator site and that systematically vary in amplitude across conditions, time, individuals and so forth. That is, an ERP component is a source of systematic and reliable variability in an ERP data set. (Luck, 2014, p. 69)

There are three main categories of ERP components (Luck, 2014):

1. *Exogenous sensory components,* which are obligatory triggered by the presence of a stimulus.
2. *Endogenous components* reflecting neural processes that are entirely task-dependent.
3. *Motor components* that accompany the preparation and execution of a given motor response.

4.3.3.1. Selective auditory attention and ERP

Many studies using neuroimaging and electrophysiological methods to examine neural correlates of selective attention have focused on the visual domain (e.g. Driver, 2001; Serences & Kastner, 2014), but results regarding visual attention have also informed theories about auditory selective attention. Already at the point in time when Hillyard and colleagues (1973) conducted their ERP experiment regarding auditory selective attention, it was well established that there are two major components of auditory-evoked potentials: firstly, a negative ERP component, peaking at around 100 ms after an abrupt sound, and secondly a positive component at approximately 200 ms. Both components are larger when the sound is attended than when it is to be ignored. Changes in an ERP component specifically reflects selective attention rather than a reactive change of a nonselective state, suggesting that the early and later components reflected fundamentally different selective attention processes, that flexibly operate together depending on task demands (Hillyard et al., 1973; see also Serences & Kastner, 2014). With regard to auditory sensory responses, attention has its first reliable effects in the mid-latency range according to Luck (2014). Long-latency responses such as the P1 and N1 can be strongly influenced by, among other factors, attention and arousal (ibid.).

In a classical dichotic listening experiment, participants were presented with two similar series of tone pips and were asked to selectively attend tones played to the designated ear (Hillyard et al., 1973). ERP responses to the same tones when attended and unattended were compared and revealed an enhanced N100 component for the attended tones. Early ERP components such as the N100, P1 and P2 are generally linked with basic, low-level perception, meaning that as long as a perceptual stimulus is presented, these components should be elicited (see also Beres, 2017, for a review).

4.3.3.2. Swedish AudAt

Early work on selective auditory attention thus focused on subtle acoustic differences, and Shinn-Cunningham and Best (2015) state that in many experimental paradigms, stimuli are manipulated to be unnaturally similar or unnaturally correlated in their timing. However, during the latest decade or so, researchers have studied selective attention in more natural, and thus complex, listening scenarios. Neville and colleagues have developed a child-friendly way of assessing selective auditory attention via an ERP experimental paradigm (e.g. Coch, Sanders, & Neville, 2005, Sanders et al., 2006), which has also been used as an indicator of intervention effects in studies targeting attention and other cognitive abilities in children from lower-SES backgrounds (Neville et al., 2013). The ERP paradigm, AudAt, is an adaption of classical dichotic listening ERP experiments, and was in turn adapted for Swedish in the studies included in this thesis.

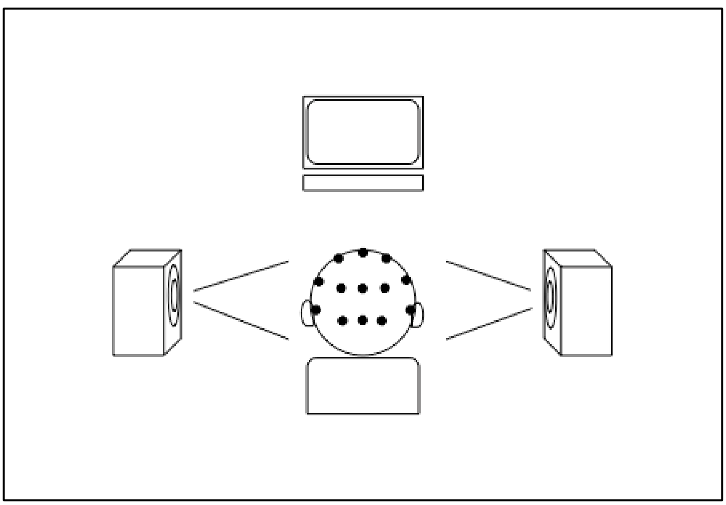

Figure 3. Experimental setup of Swedish AudAt (figure by Petter Kallioinen).

In Swedish AudAt, the child is instructed to pay attention to one of two simultaneously played stories and their brain activity is recorded with electroencephalography (EEG). Images from the attended story are displayed on a laptop to support the child in focusing on one of the stories (see Figure 3). By time-locking the brain's electrophysiological responses to probe sounds which are inserted in the stories, it is possible to obtain a measure regarding the allocation of attention to the attended story in relation to the unattended story, in other words a potential *attention effect*. This attention effect is calculated as the average difference in response to the attended and the unattended channel and is in young children expected to occur mainly as a broad positive peak at approximately 100–200 ms post stimulus onset, consistent with previous literature using the original AudAt paradigm (e.g. Coch et al., 2005; Karns et al., 2015; Neville et al., 2013; Sanders et al., 2006) and with our own unpublished pilot data. For a more comprehensive description of Swedish AudAt, including technical details and information regarding preprocessing of EEG data, see Study II and III.

AudAt is not biased by response selection and could potentially give information about children's abilities even before they are able to display selective attention in overt behavior. AudAt is furthermore described as an extremely dense or crowded auditory environment (Sanders, Stevens, Coch, & Neville, 2006), but also as a naturalistic experiment, placing similar demands on selective attention as real-life situations.

Sanders and colleagues (ibid.) investigated adults, 6–8-year-olds and 3–5-year-olds using the original AudAt paradigm and concluded that even 3-year-olds could display selective attention if the experimental setup was child-friendly, for instance providing sufficient cues in the form of visual support. However, both children and adults have previously been shown to also display a later negative attention effect, but only for linguistic probe sounds (Sanders et al., 2006).

Test-retest reliability has not been accounted for in previous studies using the AudAt paradigm with young children (e.g. Coch et al., 2005; Neville et al., 2013; Sanders et al., 2006). Coch and colleagues (2005) did not find any correlations between attention effect and reading skills, nor any significant correlations with age in a sample of 6–9-year-old children.

4.4. Assessment of mathematics skills

According to Charlesworth and Leali (2012), there are some fundamental concepts relating to mathematics in preschool-aged children: one-to-one correspondence, counting skills, shapes, spatial abilities, categorization skills, the ability to compare and to see parts and whole. Narrowing down to number sense, Aunio and Räsänen (2016) concluded that there are four core numerical skills among children aged 5 to 8: 1) symbolic and non-symbolic number sense, 2) understanding of mathematical relations, 3) counting skills, and 4) basic arithmetic skills.

There is a general paucity of appropriate assessment tools for preschoolers (e.g. Charlesworth & Leali, 2012), and as far as I am aware, there were no published Swedish math tests or assessment materials for preschoolers when data collection for the current studies was conducted, in line with the general view that individual children should not be evaluated or tested in preschool; see also chapter 5.

The test instrument *Panamath* measures the approximate number system, it is freely available online[3] and is suitable from age 3 up into adulthood. Results from Panamath predict performance in formal school mathematics (Halberda, Mazzocco, & Feigenson, 2008). Administration is easy and the software provides a detailed trial-by-trial report for each participant. Panamath was thus considered as a suitable tool to assess children's math skills for the purposes of the current studies, but has to be delivered via computer, which made it practically impossible to use.

Instead, an adaptation of *The Number Sense Screener* (Jordan, Glutting, & Dyson, 2012) was employed[4]. In its original version, The Number Sense Screener is intended for children from age 5 and intends to identify children at risk for math difficulties at an early stage, to plan effective interventions and to monitor progress. The adapted version was used to measure intervention effects regarding math and assessed children's counting skills including one-to-one correspondence, approximate number sense, number consistency and number comparisons, for instance "which is smaller, 4 or 2?", and also included story problems, assessing basic arithmetic skills.

4.5. Assessment of emotional comprehension

In outlining the research questions and design, the multidisciplinary team behind Study III discussed including a pure Theory of Mind test, such as some version of the well-known false belief tasks used in previous work. However, since one of the interventions in Study III could be defined as targeting socioemotional abilities, a broader measure of emotional comprehension was included, which to some extent taps into abilities relating to false belief understanding, although not constituting fully-fledged, reliable assessment of Theory of Mind abilities. *Test of Emotional Comprehension* (TEC; e.g. Pons, Harris, & de Rosnay, 2004; Pons, Lawson, Harris, & de Rosnay, 2003) has been employed from age 3 up into middle childhood and shows sensitivity to age-related change and is furthermore closely connected to language ability.

[3] See https://panamath.org/)

[4] In Study I, a different math assessment was used, but there were ceiling effects and the results thereof are not included in the paper.

Table 3. Overview of language and communication tests and materials reported in the current studies.

	LANGUAGE AND COMMUNICATION		
Test/material	Targeted ability	Extracted measures	Study
PPVT (Dunn & Dunn, 2007)	Receptive vocabulary	(raw score)	II-IV
The Bus Story Test (Renfrew, 1995)	Narrative retell	information score, syntactic complexity (Svensson & Tuominen-Eriksson, 2002); lexical diversity; morphosyntactic accuracy; story length (Berman, 1988)	I-III
Frog, Where Are You? (Mayer, 1969)	Narrative generation	information score (Berman, 1988; Svensson & Tuominen-Eriksson, 2002); syntactic complexity (Svensson & Tuominen-Eriksson, 2002); lexical diversity; morphosyntactic accuracy; story length (Berman, 1988)	II-IV
SCDI words (Eriksson, 2017)	Parent-rated expressive vocabulary	(raw score)	I-IV
SCDI morphology (Eriksson, 2017)	Parent-rated expressive morphology	(raw score)	I-III
Novel rating scheme (Lord; 2000; Tonér & Nilsson Gerholm, 2021)	Researcher-rated non-verbal communicative behavior	(raw score)	I, III and IV

Table 4. Overview of EF and selective attention tests and materials reported in the current studies

EXECUTIVE FUNCTIONS & SELECTIVE AUDITORY ATTENTION			
Test/material	Targeted ability	Extracted measures	Study
Dimensional Change Card Sort task Weintraub et al., 2013)	EF; cognitive flexibility	composite scores based on accuracy and response time	I-IV
The Fish Flanker Task Weintraub et al., 2013)	EF; inhibition/ interference control	composite scores based on accuracy and response time	I-IV
Forward digit span (Pickering & Gathercole, 2001)	EF; short-term memory	(raw score)	I-IV
Backward digit span (Pickering & Gathercole, 2001)	EF; working memory	(raw score)	I-II
Head-Toes-Knees-and-Shoulders (Cameron Ponitz et al., 2008)	EF; response inhibition, cognitive flexibility	(raw score)	I-IV
SDQ (Goodman, 1997)	Parent- and teacher-rated behavioral strengths and difficulties	composite score across subscales, based on both parents' and teachers' ratings	III-IV
ERP: Swedish AudAt (Coch et al., 2005)	Auditory selective attention	early and late attention effects	II-III

5. Early childhood education

The starting point of this chapter is an overview of the characteristics of Swedish preschools, including related information of the participants in the current studies, followed by a brief description of the history of Swedish preschool, the Swedish preschool curriculum and pedagogical practices. Next, a summary of Swedish preschool research is provided, including some examples of previous work within the domains of language and literacy and early mathematics. I widen the perspective by including studies from a Nordic perspective and finally I report previous work regarding evidence-based preschool interventions or programs from other, mainly North-American contexts.

5.1. Swedish preschool

Currently, 84 % of all children in Sweden aged 1–5 attend preschool. Children typically start preschool between 1 and 2 years of age and attend more or less full time until school start the year a child turns 6 years old. Among 4–5-year-olds, attendance is 95 % (Skolverket, 2016). Swedish children are enrolled to a somewhat larger extent than children with a foreign background (Skolverket 2018b). In Swedish preschool as a whole, 25 % of children have a foreign background as reported in a recent public inquiry (SOU 2020:67), but as a consequence of ethnic and socioeconomic residential segregation, the ratio of children with a foreign background as well as lower-SES is often very high in certain residential areas and largely non-existent in other areas, even within the same municipality. Children with at least one-foreign born parent and children from lower-SES families also tend to start preschool later than Swedish peers.

Preschool fees are heavily subsidized; Swedish municipalities are by law obliged to provide preschool to children from age 1 and children are entitled to part-time attendance also when the parent is on parental leave or unemployed. From 3 years of age, preschool is available for 15 hours per week at no cost for parents. The municipalities are obliged to organize this universal preschool education (Martin Korpi 2015; SFS 2010:800, kap. 8, § 4). Since 2009, there has been freedom of establishment for preschool services, and currently around 20 % of the Swedish preschool population attend independent preschools (Martin Korpi, 2015). However, all preschools in the studies of this thesis are run by the municipalities.

Swedish preschool has traditionally had a strong compensatory ambition by providing possibilities for development to children from less resourced backgrounds (e.g. Tallberg Broman, 2017; Gustafsson et al., 2010). Nevertheless, an audit by the Swedish Schools Inspectorate (Skolinspektionen, 2018) indicated that the quality of early childhood education is not equivalent across preschools, and several important areas need improvement to fulfill the intentions of the curriculum. This is in contrast to the arguments for Swedish preschool policy, which have been built on children's rights to equal opportunities (Bremberg, 2009), and it is also stated in the preschool curriculum that education should be adapted to all children in the preschool:

> This means that education cannot be structured in the same way everywhere and that the resources of the preschool should not be distributed equally. (Skolverket, 2018a, p. 6)

5.1.1. Preschool demographics in the current studies

In 2016, the year in which data collection began for the studies included in this thesis, 39 % of Swedish preschool staff had a 3.5-year preschool teacher degree. In the municipality where data for Study I was collected, the ratio was 37 %, whereas the municipality in which studies II, III, and IV were conducted had 27 % trained preschool teachers (Skolverket, 2016).

In all studies, age at preschool start was largely in line with the national average, and children in the current studies attended preschool more or less full-time. See also Table 5. We do not have access to information regarding whether or not children's parents are born in Sweden, but parents reported whether or not children spoke additional/other languages than Swedish at home, which seems a reasonable proxy for foreign background (only six of 431 children in Study II and III spoke any of the national minority languages of Sweden). The proportion of bi- or multilingual children was slightly higher than the national average number of children with a foreign background in Studies II–IV and much higher in Study I, potentially reflecting residential segregation (Table 5). Another indication of ethnic/socioeconomic residential segregation is that in Study III, bi-/multilingual children were unevenly distributed in intervention groups, with over 50 % bi-/multilingual children in the one intervention group but only 26 % in the other intervention and 22 % in the control group.

A secondary finding, in line with the above-mentioned reports on the lack of equivalence between preschools, was that preschool quality as rated with *Early Childhood Environment Rating Scale* (ECERS-3; Harms, Clifford, & Dryer, 2014) differed significantly between intervention groups (see Study

III) and there were furthermore indications of large variations in preschool quality when comparing units/classrooms within the same preschool.

Table 5. Mean age at preschool enrolment, mean weekly time at preschool and proportion of multilingual children in the current studies. Participants in Study IV constituted a subsample of participants in Studies II and III.

	Study I (n = 47)	**Study II; Study III (n = 431)**	**Study IV (n= 141)**	**National average (Skolverket, 2016)**
Mean age at preschool enrolment	20 months	18 months	16 months	17 months (median)
Mean time/week at preschool	39 hours	38 hours	38 hours	
% bi-/multilingual	49%	33%	28%	25% (foreign background)

5.1.2. Preschool history

The purpose of Swedish preschool has to a great extent been to make it possible for both parents to work, but also to promote children's well-being, learning, play and development. The first form of child care provision started in the mid-1800s as a consequence of industrialization, with the main purpose to prevent child labor and to provide full-day child care for poor, working mothers. Children from affluent families could attend kindergarten. During the 1900s, full-day care and part-time kindergartens existed in parallel. (Martin Korpi 2015; Tallberg Broman, 2017).

In the 1970s, preschool teacher training became academic, the pedagogical purpose of child-care was emphasized and a national preschool law was adopted. Still, in 1975, only 10 % of children aged 1–6 were enrolled in preschool, but during the 1970s, the presence of mothers on the labor market increased vastly and so did the demand for preschool expansion (Martin Korpi, 2015; Persson, 2017).

During the late 1990s, the Swedish preschool got its first national curriculum and preschool became part of the educational system, whereas it earlier had been considered part of social services.

5.1.3. Curriculum and pedagogy

The current preschool curriculum places focus both on education and care, with limited formal instruction in subjects such as early literacy skills or early mathematical ability (Skolverket, 2018a). The goals in the curriculum are formulated in a way that opens for several interpretations of the content, methods and implications of teaching and learning in preschool. The concept of 'teaching' in preschool was introduced as late as 2011 and has been problematized by Swedish early childhood scholars, for instance that it is unclear what teaching in preschool entails (e.g. Nilsson, Lecusay, & Alnervik, 2018), and that it places high demands on teachers' ability to implement theoretical perspectives and make adequate didactic choices (Björklund, Pramling Samuelsson & Reis, 2018).

Swedish preschool working methods do not involve any formal assessment of children's individual skills, although the curriculum states that the preschool should provide each child with opportunities to develop abilities such as cooperation, conflict management, mathematics, communication, and nuanced use of spoken language (Skolverket, 2018a). The type of evaluations conducted in preschools are applied to the preschool as a function, rather than focusing on children's individual skills or learning. It is argued that it is not possible to capture the process of learning or to understand children's knowledge in relation to preschool conditions in individual assessments, tests or screenings. Individual assessment can in this view only provide information regarding a certain skill at a certain point in time, possibly in relation to some normative developmental scale (Åsén & Vallberg Roth, 2012).

Attempts to implement a school-like curriculum or methods in Swedish preschools, including evaluation of individual children's performance, have been described as carrying risks that children experience failure already in preschool. A large number of Swedish educational researchers stated that:

> …it would be more useful to focus on general measures in order to sustain and stimulate the development of children in preparing them for school, than to perform assessments merely to control if the children fail to reach the goals of the curriculum. (Gustafsson et al., 2010, p. 157)

It may be a relevant point that preschool staff should not assess children, but instead focus on stimulating children's development. A similar concern has been raised by Hirsh-Pasek, Golinkoff, Berk, and Singe (2008), who provided counterarguments to the rising tide of didactic instruction in preschool classrooms. However, it is remarkable that the impact of preschool has not been more closely investigated in early childhood research, see also Section 5.2 below.

Current pedagogical practices emphasize children's socialization and play as vehicles for learning. According to Lenz-Taguchi (2008), Swedish preschool has during the 20th century and continuing up until today, been characterized by the notion of 'the good childhood' and of ideas about children's inherent traits and skills, which have been thought to change in a stage-like manner. Such ideas have however been strongly rejected by Swedish early childhood scholars, an attitude which is consequently reflected in the preschool teacher education and practices. Since the early 1990s, Swedish preschools, not least in the Stockholm region, have been inspired by the Italian preschools in Reggio Emilia, in search for alternative ways to understand learning in early childhood (e.g. Lenz-Taguchi, 2008; Nilsson, Lecusay, & Alnervik, 2018). In Sweden, post-structural theories have been extensively incorporated with the Reggio Emilia approach (Lenz-Taguchi, 2008).

5.2. Preschool research

5.2.1. Swedish preschool research

According to Swedish school law (SFS 2010:800, kap. 1, § 5), preschool should rest on a scientific basis. Note that the wording is not that the preschool should be evidence-based. Early childhood research in the Swedish context has so far rarely included evaluations of pedagogical working methods in terms of their effects on children's development. Randomized controlled trials are very scarce, not only in Sweden but also from a Scandinavian perspective, although an increase can be seen during later years, in part due to political strategies to combat negative social inheritance (see e.g. Jensen, Holm, & Bremberg, 2013).

Training studies targeting EF in preschool-aged or young school-aged children have been conducted in Sweden (e.g. Thorell et al., 2009), but not from the perspective of evaluating aspects of existing preschool pedagogical practices. Systematic and quantitative evaluation of interventions, working methods or practices that aim to reach all children in preschool, not specific subgroups or at-risk populations, have been largely non-existing in the Swedish context.

Language and literacy research within the framework of Swedish early childhood studies has focused on teachers' ability to create a preschool environment that is considered to be beneficial for children's language (see Tallberg Broman, Vallberg Roth, Palla & Persson, 2015, for a summary). For instance, a recent Swedish study by Brodin and Renblad (2019) investigated how reading and storytelling may influence children's communication development in a sample of 573 preschoolers from 23 preschool units. The authors conclude that reading aloud and storytelling can be used to support speech and language development. However, individual children's outcomes were not measured, instead the outcome measure was a questionnaire regarding teachers' attitudes, knowledge and activities regarding reading.

Early childhood research regarding mathematics in preschool has for instance been related to teacher learning and reflection in order to improve pedagogical practices related to early math, or has investigated how children's math knowledge can be enhanced by using technological artifacts (see Tallberg Broman et al., 2015, for a summary).

Children's access to digital tools and the opportunity to develop digital competence are highlighted in the most recent update of the preschool curriculum (Skolverket, 2018a), but research regarding effects of digital tools is rather scarce and results are inconclusive with respect to beneficial effects on children's learning and development (see also Study III). For the past decade, digital tablets, as well as other digital tools have been widely used in Swedish preschool (see Kjällander & Frankenberg, 2018, for a summary), but usually not in terms of individual training programs.

Gustafsson and colleagues (2010) conducted a review on school, learning and mental health, including children aged 2–18. Authors included a qualitative review of Swedish studies, but the experiences of preschool children are not represented at all and the conclusion is that the knowledge base in general is limited, in particular with regard to teaching methods and activities (ibid.).

It may seem intriguing that there has been so little research regarding the effects of existing pedagogical working methods on cognitive skills or on other aspects of development. However, among educational researchers in Sweden there is a widespread skepticism with regard to some of the core principles in intervention methodologies, including resistance against testing of individual children's abilities. The field of early childhood education has instead been dominated by small-scale qualitative praxis-oriented and participative research (see e.g. Frankenberg et al., 2018).

5.2.2. Preschool research in the Nordic countries

From a Nordic point of view, Dale, Logan, Bleses, Højen, and Justice (2018) examined effects of a language and emergent literacy intervention in Denmark and showed that children who had lower scores at pretesting gained more than those who had higher scores before intervention. Recently, Bleses and colleagues (2018) conducted a cluster-randomized evaluation of language and literacy instruction in a sample of over 5 000 children aged 3–6 in Danish preschools. The Danish preschool system is very similar to the Swedish system, both with regard to the nearly universal enrolment of children, at least between 3 and 5 years of age, and also considering the absence of specific academic learning goals. Furthermore, in the words of Bleses and colleagues "…an empirical basis for practices is not available." (Bleses et al., 2018, p.

258). The intervention in which teachers could determine the details of the instructional activities but followed a certain scope and sequence led to the largest gains in children's abilities. Non-Danish children benefited more than native Danish children from higher exposure for language outcomes, and there were no moderation effects of SES (ibid.). Another Danish intervention study included over 2 000 children and evaluated a program in which teachers were encouraged to provide each child with suitable learning opportunities and to arrange situations that would minimize exclusion for disadvantaged children. The overarching goal for the teacher was to recognize every child's progress and to encourage the children to embark on new activities and explore new sides of themselves (Jensen, Holm, & Bremberg, 2013). The SDQ (e.g. Goodman, 2001; Niclasen et al., 2013, Section 4.3.2 above) was used as an outcome measure and the intervention group performed better than controls with regard to emotional symptoms, conduct problems and hyperactivity/inattention but the effect sizes were small (ibid.). Recently, Grøver, Rydland, Gustafsson, & Snow (2020) conducted a cluster-randomized intervention study in Norway. Participants were 3–5 years old and were acquiring Norwegian as a second language and they received an intervention organized around shared book-reading in preschool and at home. Compared to the control group, the intervention group showed significant gains in second language skills (ibid.).

The Public Health Agency of Sweden (Folkhälsomyndigheten, 2017) conducted a review of preschool and child health, published shortly after the completion of data collection for the current studies. Very few of the studies included in the review were conducted in Sweden, but the report emphasizes research from the Nordic countries. The report states that it is difficult to compare children who attend preschool and those who do not, since such a vast majority of children in Sweden and in the other Nordic countries do attend preschool. Studies included in the review regarding general effects of preschool were conducted by economists and were to a large extent so-called natural experiments. Altogether, the research base indicates that children who attended preschool perform better at language and math and have higher educational attainment as adults compared to children who did not attend preschool. However, the results should be interpreted with caution since they are based on a very small number of studies and it is unclear how outcomes have been measured. With regard to structural aspects of preschool, such as group size, teachers' educational level and teacher-to-child ratio, the report states that there are shortcomings in the evidence-base and encourages future studies that investigate preschool-related effects on children's cognitive development, using a stringent methodology with at least a 6-month follow-up. The report also brings up the potential lack of generalizability of results from other contexts to Swedish conditions (ibid.).

5.2.3. Evidence-based early childhood intervention

International studies have revealed that a broad range of early educational interventions can have lasting effects on cognitive, behavioral, health and academic outcomes (e.g. Barnett, 2011; Nores & Barnett, 2010). Early intervention has often been regarded as a way to partially offset the impact of poverty and programs evaluated in research has therefore targeted children from low-income families.

> To me, the most basic question became whether individuals from highly vulnerable populations could benefit significantly if given more adequate resources for fuller development of cognitive abilities and socioeconomic status. Chief among these resources were health care, good nutrition, family-oriented social services, and early childhood education. (Ramey, 2018, p. 528)

The Perry Preschool Program, targeting African-American children from lower-SES backgrounds, led to gains in reading and math lasting into adulthood but also increased earnings and less dependency on social welfare (Barnett, 1985; 2011). Another well-researched program is The Abecedarian approach, which was employed in two larger longitudinal studies targeting children from infancy up to 5 years of age from highly disadvantaged families, and consisted of both full-day child care provision and parent training. The outcomes in the intervention groups compared to control supported the hypothesis that high-quality early education can prevent the cognitive disadvantage that is associated with poverty and additional environmental risk factors (see Ramey, 2018, for a summary). A research-based program aiming at improving outcomes in preschool-aged children from lower-SES backgrounds, providing both child-training and parent-training, led to gains in auditory selective attention and nonverbal IQ after an intervention period of 8 weeks (Neville et al., 2013).

Remarkably few international studies have investigated long-term effects of more general aspects of preschool attendance such as age at preschool enrolment and the amount of time spent at preschool. Loeb, Bridges, Bassok, Fuller, and Rumberger (2007) examined effects of preschool on later academic achievement in American children enrolled in Head Start and showed that academic gains were significant for children who started preschool at 2–3 years of age but not for children who started at younger ages. Burger (2010) conducted an international systematic review regarding preschool and concluded that preschool experience contributes to school readiness in a majority of studies (no Swedish studies were included). However, the findings regarding age of preschool enrolment and amount of time spent at preschool were inconclusive. Longer preschool interventions did not necessarily lead to better outcomes with regard to cognitive abilities. Furthermore, preschool attendance did not seem to compensate for SES-related differences in cognitive skills.

Language-focused interventions aim at enhancing children's language skills by increasing their opportunities to participate in linguistically rich conversation, based among other things on claims that the crucial ingredient in successful early childhood educational settings is the inclusion of responsive and cognitively stimulating daily interactions between teachers and children (Hamre, 2014). However, long-term effects of such language interventions are rarely seen (e.g. Johanson, Justice, & Logan, 2016). Preschool interventions or curricula targeting language that have been evaluated during recent years include the Learning Language and Loving It program, which led to long-term effects on children's reading abilities, although effects on vocabulary faded out (Johanson et al., 2016). Children who did benefit from the intervention had relatively high levels of language skills in preschool, so the program would not seem suitable to diminish language differences. A study by Neville and colleagues (2013) revealed that children improved their receptive vocabulary score after an 8-week intervention period consisting of both child and parent-training. With regard to more general findings regarding language development in the age group 4–6-year-olds, a large Australian study including over 1 900 children indicated that it also is possible to modify children's language trajectories after the early years (McKean et al., 2015), which would suggest that preschool-based interventions or pedagogical practices can potentially have great impact on children's abilities. McKean and colleagues furthermore suggested that future studies should seek to determine whether differences exist between (pre-)schools with respect to children's language development.

There are several programs or curriculums that are implemented in preschool classrooms in the U.S. that show indications of beneficial effects in particular for EF. The *Promoting Alternative Thinking Strategies* (PATHS) curriculum is a universal and school-based program which aims at promoting emotional and social skills as well as reducing behavioral problems in children aged 4–11 (Kusché & Greenberg, 1994). PATHS is based on the idea that the intervention will lead children to recruit language to regulate behavior and to communicate effectively and is thus in line with a view that EF can be verbally mediated. The preschool version of the PATHS curriculum has been adopted in Head Start's research-based developmentally informed classroom curriculum in the U.S. (Nix et al., 2016). Effects of PATHS were recently examined in a review by Stanley (2019), who concluded that preschoolers' social skills improved, but that there was not compelling evidence that PATHS reduces children's problem behaviors. *Tools of the Mind* is yet another early childhood curriculum with the goal to help children learn how to become masters of their own behavior, and includes activities that promotes children's social, emotional, and cognitive self-regulation (Bodrova & Leong, 2007). A Campbell systematic review and meta-analysis included 6 randomized controlled trials of *Tools of the Mind* and indicated that neither task-based nor rating-based EF improved significantly (Baron et al., 2017). The authors concluded that the evidence does not conclusively demonstrate that *Tools of the Mind* works as claimed by the developers and suggest that small-scale studies are needed to identify the core components of the program and to optimize teacher training. Baron and colleagues (2017) furthermore stated that randomized controlled trials (RCTs) within the field of preschool interventions are rather scarce, and the small number of studies reduces power. Another program with documented effects on EF is the *Chicago School Readiness Project*. Watts, Gandhi, Ibrahim, Masucci, and Raver (2018) conducted a cluster-randomized preschool intervention study in which children from high-violence and high-crime areas were assessed at the end of preschool and then participated in a follow-up approximately 10 years after program completion. Some positive long-term effects on EF and students' grades were present, and the authors conclude that the results regarding long-term effects are promising but inconclusive (ibid.). Evaluations of public programs such as curriculums included in Head Start in the U.S. thus show mixed results (see also Barnett, 2011). Furthermore, highly successful interventions have typically been implemented in groups with a high teacher-to-child-ratio, highly trained teachers and regular support from research staff, making them difficult to scale up.

6. The studies and their contributions

6.1. Study I

Relationships between different aspects of language skills and EF are frequently reported in the literature (see also chapter 3), but little is known if similar results would be obtained in a sample of typically developing Swedish children. Previous work regarding potential language–EF connections in Swedish children has primarily been conducted with clinical samples (e.g. Lindquist et al., 2008; Rejnö-Habte Selassie, Viggedal, Olsson, & Jennische, 2008). A challenge with respect to replicating earlier findings from other linguistic and cultural contexts is that EF and language tests need adaptations, and materials with Swedish norms are scarce. Moreover, EF abilities have often been in the foreground in previous studies on language–EF associations, and measures of language have often been limited to aspects of vocabulary.

In Study I, a pilot study, a range of language and EF skills was examined in 47 mono- and multilingual Swedish children aged 4–6 to shed further light on relationships between aspects of these abilities as well as potential associations to age, sex, SES, language background and aspects of preschool attendance. The prediction was that previous results regarding language and EF correlations would replicate in a sample of Swedish preschoolers and that submeasures of EF would correlate with one another, in support of a view that EF is a unitary construct in early childhood. A further hypothesis was that age would be associated with all measures and that SES would show a significant relationship with both language and EF. Additionally, the applicability of tasks previously not used in the Swedish context was examined from a practical point of view.

The context of the data collection for Study I was a pilot intervention study which allowed for two rounds of testing, enabling necessary adjustments and changes in test tasks and in the overall procedure. Study I reports results from test round 2. The final language assessment included a story retell task – *The Bus Story Test* – from which several language measures were extracted on the basis of orthographic transcriptions (see also Section 4.2.1 above). The receptive vocabulary test PPVT-4 was administered but results thereof are not reported as recommended by reviewers. Additionally, a novel rating scheme of non-verbal communication was employed. EF assessment consisted of *Dimensional Change Card Sort* task and the *Fish Flanker Task*, administered via tablet, *Head-Shoulders-Knees-and-Toes* and forward and backward digit span tasks (see also Section 4.3.1). In addition, a math test and TEC were included, but not further reported in the study. Parents filled out the SCDI-III and an extensive questionnaire regarding background information.

Correlations between the different language measures were generally high, whereas the different EF measures did not correlate with one another across the board. Based on the correlational pattern, an EF composite measure was obtained, in line with the conception of EF as unitary in young children. Language and EF correlated to a large extent but also showed some variability. To explain variance in the language and EF measures, regression models with a backward selection procedure were computed. In line with predictions, age was a significant predictor of language measures and of EF composite measure. Contrary to expectations, results could not confirm a female advantage for language. However, the communication ratings revealed a significant difference – girls were rated higher than boys – which should however be interpreted with caution, since the rating scheme was novel and not validated. There were no associations to SES for either language or EF, however the sample was skewed toward higher SES.

The main contribution of Study I is that by employing several language and EF measures, it gives a fuller picture of the nature of the relationship. Yet, further research with a larger sample is warranted. The results indicate that there may be a stronger association between aspects of syntactic skills and cognitive flexibility and between overall grammar skills and inhibition, which is in line with previous empirical as well as theoretical work (e.g. Ibbotson & Kearnell-White, 2015; Zelazo, 2015). Results also suggest that relying on measures of vocabulary may lead to overestimating the strength of the language–EF relationship. Age was a significant predictor of all measures, which could be considered trivial, but is reassuring considering the lack of Swedish norms for many of the tests and tasks employed. Still, the predictive value of age was rather modest and potential differences between and variability within age groups need further attention. We found no significant language differences when comparing monolingual and bi-/multilingual children, in line with previous work stating that narrative assessment may be less biased than other kinds of language tasks when investigating bilingual children (e.g. Heilman et al., 2019). Having additional languages in the home was not a significant predictor of any outcome variable. Ratings of non-verbal communication indicated significant individual variability within the same assessment session, highlighting the potentially large impact of small contextual variations. Another contribution is that the study gives some ideas about improvement of tests, such as assessment of receptive vocabulary and auditory working memory.

6.2. Study II

The second study expands on Study I by employing the same measures in a far larger sample of 431 Swedish children aged 4–6. For a subsample of 138 children Study II also included an ERP measure of selective auditory attention, Swedish AudAt, which did not require any behavioral response (see Section 4.3.3.2). In the ERP paradigm, the child was instructed to selectively attend one of two simultaneously played stories, each of which had probe sounds to which the brain responses are time-locked, thereby making it possible to obtain a measure of the attention effect, in other words the difference in response to the attended versus the unattended story. ERP recordings were conducted on-site at the child's preschool.

It was assumed that results from Study I as well as previous work regarding associations between language and EF would replicate in a larger sample and moderate correlations between language and EF measures were therefore predicted. A significant association between behaviorally assessed EF and the ERP measure of selective attention was expected, since selective attention could either be regarded as foundational for EF, or could be viewed as recruiting EF in the form of cognitive flexibility/shifting and inhibition, specifically interference suppression. Similar to Study I and in line with previous work, the hypothesis was that age and SES would predict language, EF and selective attention performance. Potential differences between girls and boys and between monolingual and multilingual children were explored, as well as possible associations to aspects of preschool attendance and quality.

The participants in Study II were the same as in Study III, and analyses are based on pre-test data. However, closer examination of pre-test results was conducted after analysis of intervention effects (Study III, in which analysis was restricted to the strategies described in Gerholm et al. (2018)). The main analytic strategy for Study II was multiple regression analysis and, in addition, non-parametric correlations were computed for all language, EF and attention measures.

Differently from Study I, all EF measures correlated significantly with one another; the correlations were weak to moderate. The correlations between language measures and separate EF measures were moderate at best, and thus weaker than expected. There was an overall attention effect, in other words a significant difference in response to attended versus unattended stimuli in the ERP experiment, but, contrary to predictions, there were no correlations between behaviorally assessed EF and selective auditory attention. In regression models, proportion of explained variance was largest for receptive vocabulary (40 %), then EF (29 %), then morphosyntax (13 %) and lastly selective auditory attention (9 %). Age was positively associated with receptive vocabulary, morphosyntax and EF but not selective attention, and male sex was a negative predictor for all outcome measures except attention, thus indicating a female advantage for language and EFs in the current sample. Contrary to Study I, multilingualism was associated with lower receptive vocabulary score (only the majority language was assessed), also when controlling for SES. There were no significant results of preschool-related measures on language, EF or selective attention.

Similar to Study I, the current study expands current knowledge regarding the language–EF relationship by employing several language and EF measures, including ERP, but in a vastly larger sample. A specific example includes the finding that morphosyntactic accuracy and story length showed a (weak) correlation with attention, providing further support for the idea that morphosyntax may have specific links to aspects of cognitive flexibility as well as inhibition (e.g. Gandolfi & Viterbori, 2020; Ibbotson & Kearnell-White, 2015; Zelazo, 2015); as suggested by preliminary results in Study I. Another example of such clarification regarding associations between language and EF is that results suggest that relying on measures of vocabulary may lead to overestimating the strength of the language–EF relationship, which was also indicated by Study I, but here confirmed in a much larger sample.

The results regarding selective auditory attention, for instance the lack of association with age, give rise to questions about the validity of Swedish AudAt. However, previous work did not find correlations between attention and age (Coch et al., 2005), and in general, reliability of ERP components is an area where more research is needed (e.g. Huffmeijer et al., 2014).

In Study II, parental income and educational level were coded separately for each parent, as opposed to the SES composite measure employed in Studies I, III and IV. Such a procedure makes it possible to find potential differentiated effects of various SES-related aspects, but comes with the downside that model estimates may be more difficult to interpret. Nevertheless, such a procedure revealed specific effects of parental education and income on receptive vocabulary, and effects of parental education on morphosyntactic accuracy, EF and selective attention.

To conclude, future studies should try to recruit participants from a range of socioeconomic backgrounds. Aspects of preschool attendance, such as age at preschool enrolment, need further attention, not least since a majority of Swedish children start preschool at 1–2 years of age. More work is needed to develop and evaluate language and EF assessment materials but, perhaps more importantly, to develop and refine testable theories regarding the nature of the relationship between language and EF.

6.3. Study III

In Sweden, a vast majority of children 1–5 years of age attend preschool. However, intervention research is less common than in, for instance, the North American context (see also Section 5.2). Due to the large societal and cultural differences, results from other contexts are not readily transferable to the Swedish preschool setting. Not only do we know little of the effects of preschool practices or aspects such as age at preschool enrolment,but also there is a knowledge gap with regard to how socioeconomic background affects children's development in a context where most children go to preschool more or less full time. Furthermore, successful interventions have often targeted children from lower-SES backgrounds, but results have not replicated in samples of higher-SES children.

In Study III, the goal was to investigate potential effects of two contrasting pedagogical working methods, which to some extent were already employed in Swedish preschool, though evidence for either of them was lacking. One intervention was based on socioemotional, group-based learning centered around a common learning objective or theme (SEMLA). The other intervention, DIL, consisted of individual math training in a responsive game, delivered as a tablet application, in combination with attention-enhancing, self-regulating exercises, inspired by work by Neville and colleagues (e.g. Neville, 2013). The socioemotional intervention was believed to affect children's outcomes indirectly, for instance that EF could be improved by processes of verbal reflection, rather than by direct training of a specific EF skill. In contrast, the math/attention intervention could be conceived of as having more direct effects. Specific activities targeting selective attention would be expected to lead to gains in selective attention as measured by ERP in the Swedish AudAt paradigm.

Both interventions were delivered by the educators at each preschool. A control group, conducting business-as-usual was also included in the cluster-randomized controlled trial. An array of research questions and hypotheses was formulated, with the overarching expectation that intervention groups would gain more on all outcome measures compared to controls. Research questions, hypotheses and analytic strategy were published as a study protocol prior to data analysis (Gerholm et al., 2018). The details of each intervention, including teacher training, were formulated by early childhood/preschool didactics researchers, whereas researchers from linguistics and psychology were responsible for the selection and design of outcome measures. Participating preschools were recruited from a municipality in the Stockholm region which had an ongoing collaboration with the Department of Child and Youth Studies at Stockholm University and 18 preschools opted in. Following information meetings, guardians of 431 children gave consent for their children to participate in the evaluation of the interventions.

Testing took place at the child's preschool within two weeks before and after a six-week intervention period. As primary outcome measures, behavioral tests of language, EF, early math and emotional comprehension were combined with Swedish AudAt, for a subsample of participants. The test battery was selected based on the experiences from Study I and included assessment of receptive vocabulary, narrative tasks (different tasks at pre- and posttesting to avoid training effects), an array of EF tasks, an emotional comprehension task and an early math task. Language and EF were summed into two composite scores.

Results were mainly analyzed using mixed models regressions, taking into account the nested structure of the data. The planned univariate regression analysis did not indicate any intervention effects. Due to high intercorrelations among outcome measures, an additional multivariate analysis was conducted in addition to the planned analyses, but revealed no significant intervention effects. ERP-specific regressions did not reveal any intervention effects on selective attention, although there was a significant overall difference between attended and unattended responses, in other words an attention effect (see also Study II).

Although a number of background factors and test results at pretest were controlled for in the statistical model, further exploration of intervention group differences was conducted. It is theoretically possible that such differences could to some extent affect intervention delivery on behalf of the teachers or intervention uptake from the perspective of the children. As an unwanted effect of the cluster randomization, there were some differences between groups, including higher SES, higher preschool quality and higher preschool attendance in the control group compared to both intervention groups, significantly younger children in the math/attention group compared to controls, and larger proportion of bi-/or multilingual children in the socioemotional intervention group compared to the other groups.

In spite of quite intense math training, children in the math/attention group did not improve on the math test. This result raises questions about (lack of) transfer in general, but specifically about learning in digital applications, which are designed to be pedagogical. It has been suggested that children progress through a learning game by means of trial and error as opposed to actually learning the intended content (Nilsen, 2018), which needs further attention in pedagogical research.

Looking beyond intervention effects, pretest scores as well as age predicted posttest scores, providing some preliminary indications that the measures were reliable, although future work should be conducted to reveal the psychometric properties of the tasks at hand. Contrary to Study I and II, SES predicted EF, but not language. It should be mentioned that a composite SES score was used in Study III, whereas in Study I and II, income and educational level were coded separately for each parent. In line with indications from Study I, children from bi- or multilingual backgrounds had significantly lower

SES than monolinguals. Additionally, higher-SES children tended to spend more time at preschool. Study III also confirmed language–EF correlations in Swedish preschoolers, but on a more general level compared to study II, since composite scores were used.

An optimistic interpretation of the lack of intervention effects is that regular Swedish preschool (at least when of high quality) does a good job of stimulating children's cognitive development, but further work is clearly needed to pinpoint eventual effects of different aspects of preschool attendance and pedagogical working methods. In the future, intervention studies should be conducted in lower-SES areas where learning potentials are expected to be greater. Future studies should do more pilot testing and quasi-experimental designs to carefully investigate intervention components as well as outcome measures to ensure that they are valid in relation to the goals of the interventions. The interventions or working methods themselves were perhaps not ready for trial. In particular the SEMLA intervention seemed fairly difficult to implement, and intervention fidelity was rather poor with regard to both dosage and quality. From the point of view of the early childhood scholars who designed SEMLA, the intervention was conceptualized as a refined version of existing pedagogical working methods. The implementation challenges could indicate a mismatch between the perceived and actual competencies and capacities of early educators.

Although it may sound trivial, one of the main contributions of Study III is that it was at all possible to conduct an RCT in the context of Swedish preschools, despite the ongoing controversy about such research designs in pedagogical settings (see Frankenberg et al., 2018; and Section 5.2 above) and moreover to publish the null results of such a study. To quote Styles and Torgersen (2018):

> A key lesson we can learn from history is to embrace 'null' or negative findings as enthusiastically as we tend to do with positive findings. (Styles & Torgersen, 2018, p. 256)

A bold way of stating the contributions of Study III would be to say that such groundbreaking work as the current study will hopefully pave the way for creating an evidence-based Swedish preschool and for more interdisciplinary work within early childhood research.

6.4. Study IV

In the wordless picture book *Frog Where Are You?* (Mayer, 1969) the main theme is that a boy is looking for his lost frog in various places. At one point, he climbs up a rock and holds on to something which he presumably believes to be some branches but they turn out to be the antlers of a deer. Previous work based on corpus data from children and adults show that it is rare for children to explicitly mention and explain this event in terms of mentioning the mismatch between the (fictional) reality and the perception of the boy and to link the boy's misunderstanding with the preceding and following story events (Aksu-Koç & Tekdemir, 2004).

To change perspectives between describing what happens in a story and explaining the reasons for those events requires the narrator to infer the internal states of protagonists (e.g. Küntay & Nakamura, 2004), an ability which is claimed to rest on quite advanced Theory of Mind abilities (Fernández, 2011). Theory of Mind, in turn, seems to be associated with higher cognitive functions such as EF (e.g. Austin, Groppe, & Elsner, 2014, see also Section 2.1.2). To close the circle, EF also seems intrinsically involved in constructing a narrative. Linguistic aspects that may be vital to *express* a false belief may include the ability to formulate embedded propositions or to have access to metacognitive vocabulary. Additionally, there may be factors related to the child's environment that can help our understanding of variation in children's abilities to relate internal states of story protagonists.

In study IV, frog story narratives from 141 4–6-year-old children, collected within the framework of Study III, were analyzed, focusing on the specific misrepresentation regarding the boy, the antlers and the deer, and categorizing children's responses according to the misrepresentation hierarchy used by Aksu-Koç and Tekdemir (2004). The focus of the analysis was the extent to which children in the current sample would mention and explain the fictional false belief and if the level of explicitness could be related to language and communication skills, EF and/or emotional comprehension skills. Potential differences in misrepresentation ability related to children's age, SES, sex, presence of additional languages than Swedish and preschool quality in terms of language, literacy and interaction were examined with ordinal regression analysis.

In line with expectations, explicating or hinting at the fictional false belief was very rare; very few children included complete explanations in their narratives and those who did were all above 5 years of age. The only language measure that was associated with children's level of explicitness was information score, in other words children who included a lot of information in the story tended to be more explicit with regard to the fictional false belief. Results also indicate that children's use of mental vocabulary may be an important factor, but further work is needed to investigate if children's use of internal state words varies systematically with their level of explicitness. Results regarding EF were inconclusive and emotional comprehension was not associated with level of explicitness. There was a significant association to SES but not to any other background variables, including age.

The lack of experimental manipulation at the point of data collection means that the data reflect children's proneness to spontaneously include such information in the current setting. The context may not clearly have signaled a need for the child to include explicit information regarding the false belief. Future studies should select elicitation materials carefully, manipulating aspects of the set-up such as to whom the child is telling the story. Further analyses should also take multimodal and prosodic aspects into account, such as children using gesture, facial expressions and vocal characteristics to convey the false belief, as well as investigating and quantifying expressions of internal states. The Swedish preschool curriculum emphasizes book-reading and future work should include preschool observations and analyses of teacher-child interaction in conjunction with shared book-reading, which would serve both to shed further light on children's narrative development, and to form the basis for evidence-based pedagogical practices in Swedish preschool.

7. General discussion and conclusion

This dissertation is one of the first examining concurrent relations between several aspects of language, EF and selective auditory attention in Swedish 4–6-year-old children. Measures were obtained combining a range of behavioral tests, collecting ecologically valid and linguistically rich language samples in the form of narratives, parent and teacher ratings and an ERP paradigm measuring auditory selective attention. The main findings are summarized and discussed below.

7.1. Main findings

7.1.1. RQ 1. Associations between language and EF

Correlations between a range of language and EF measures were examined, showing overall weak to moderate associations. Results indicated that there appear to be relatively stronger associations between:

1. Aspects of syntactic skills and cognitive flexibility
2. Broader grammar skills and behaviorally assessed inhibition
3. Selective auditory attention and grammar
4. Selective auditory attention and language composite measure

The association between aspects of grammar and inhibition/selective attention is in line with previous findings (e.g. Ibbotson & Kearnell-White, Gandolfi & Viterbori, 2020, Kaushanskaya et al., 2017). The current findings could be interpreted as converging with theoretical suggestions that EF may be verbally mediated (e.g. Zelazo, 2015), for instance that the child's syntactic ability enables the formulation of increasingly complex rules that guide behavior. The association between selective attention and grammar provides some support for the idea that selective auditory attention can be reinterpreted as interference suppression, in other words, an aspect of the EF component inhibition.

The selective attention ERP measure correlated with submeasures of language and was also significantly associated with the language composite measure employed in Study III. However, contrary to expectations, the attention effect was not associated with behaviorally assessed EF, including the *Fish Flanker Task*, which purportedly also measures resistance to interference. This is an intriguing finding and further work is needed to disentangle potential subcomponents of interference control, investigating the potential impact of modality (visual as in the flanker task, versus auditory in AudAt) and other contextual factors. However, results are in line with results by Klenberg et al., (2001) who showed that selective attention and EF loaded onto separate factors.

In Swedish AudAt, the voices telling the stories spoke with a higher level of engagement, prosodic variation and character speech compared to the original version of the paradigm. This may have driven exogenous, stimulus-driven attentional processes, as opposed to task-driven, voluntary endogenous processes. To achieve a meaningful measure of selective attention that is completely free from automatic processes does not seem likely; the earliest accounts of selective auditory attention include statements that what is attended and what is suppressed depends both on volitional attention and inherent stimulus salience (Broadbent, 1958).

Furthermore, AudAt could be considered one of the most problematic measures with regard to task impurity. The other EF tasks did admittedly involve verbal instructions, but no verbal responses were required from the child – except in digit span tasks – and verbal instructions were kept to a minimum. On the other hand in AudAt the children's task was to listen to complex discourse-level language in the form of stories. However, on a functional level, auditory selective attention would not be very useful if not connected to language in some way. What would be the point of selectively attending linguistic material if one cannot process the content? Experiments with adults (e.g. Oberfeld & Klöckner-Nowotny, 2016) have shown that variance in speech comprehension in noisy environments could in part be explained by selective attention. The question that arises is: Can language ability and attention be completely separated in an experiment such as the AudAt and, moreover, is such a separation meaningful for real-life interaction? It seems reasonable to think that there is a reciprocal concurrent relationship between language processing/comprehension and selective auditory attention, so that good attention skills aid language comprehension, but strong language skills, including making probabilistic predictions about linguistic events in the near future, also support attentional processes. To find out whether AudAt can capture attentional skills regardless of language capacities, one would need to identify groups of children with strong selective auditory attention as measured with AudAt but weak language skills and vice versa.

7.1.2. RQ 2. Associations to background factors

The second research question concerned potential associations between on the one hand language, EF and attention, and on the other, factors relating to the individual child, such as age and sex, and his/her social environment, such as SES, growing up with more than one language, and aspects of preschool attendance and quality.

7.1.2.1. Age

Age was related to all outcome measures, except for auditory selective attention. This may be a consequence of the very different nature of AudAt – not only in terms of methodology (ERP versus behavioral measures) but also in terms of AudAt being an experiment designed to capture effects on a group level, which is likely less stable over repeated tests of the same person (see also Hedge, Powell, & Sumner, 2018). Language and EF tests are instead constructed to enabling tracking the progress of an individual. However, since previous work with the original AudAt paradigm reports age-related development (e.g. Hampton-Wray et al., 2017), it is somewhat intriguing that no age effect was found in the current sample. The subsample for ERP was randomized, but there was an element of self-selection since children themselves could decline participation. This procedure may have affected the sample so that it is not completely representative of the full sample. It should also be pointed out that the original AudAt primarily investigated attention in lower-SES samples (e.g.; Neville et al., 2013; Stevens et al., 2009), as opposed to the higher-SES sample of the current studies.

7.1.2.2. SES

Except in Study I, significant associations were found between the child's socioeconomic background and language, EF and selective attention, although the sample was skewed toward higher SES. Current results are in contrast with work which has failed to find such a connection between language and SES in Swedish preschoolers (e.g. Bohnacker, Lindgren, and Öztekin, 2016; Öberg 2020). For EF in Swedish preschoolers, the knowledge basis regarding SES is largely non-existing. Possible SES effects need further consideration in the Swedish context. Future preschool interventions should target children at risk for future language and EF difficulties, including children from lower-SES backgrounds, in line with a body of research indicating lower-SES as a clear risk factor with regard to linguistic and cognitive development.

7.1.2.3. Sex

The current results provide some support for a female advantage for language, in the form of stronger skills with regard to receptive vocabulary and morphosyntactic accuracy. Earlier work has indicated that girls outperform boys at an early age on aspects of language (e.g. Eriksson et al., 2012) and our results suggest that the sex-related differences in language performance are still present in 4–6-year-olds. Results regarding sex differences in non-verbal communication were inconclusive but suggesting stronger performance in girls compared to boys, and it should be pointed out that the rating instrument for communication was new and not validated. A tentative conclusion is that expectations on girls' and boys' language and communication differ. As a consequence, children's linguistic and social environments may vary, perhaps systematically, to give rise to a female advantage for language. Further investigation of language differences in girls versus boys is warranted. If our results are confirmed in future studies, preschool practices need to target the language development of boys more specifically to avoid early sex differences that may have consequences for later academic achievement. Potential differences between girls and boys with regard to EF were examined, but results were inconclusive, in line with a recent review concluding that there is little support for significant sex differences in EF (Grissom & Reyes, 2019).

7.1.2.4. Bi- and multilingual children

Multilingual children constituted almost half of the sample in Study I, 33 % of the sample in Studies II and III, and 28 % in Study IV. Study I showed that there were no differences on any of the language measures employed when comparing mono- and multilingual children, providing support that the chosen measures did not disfavor multilingual children. However, in Study II, being multilingual was associated with lower receptive vocabulary in Swedish when controlling for SES. This is in line with results from a large-scale Danish study (Højen, Bleses, Jensen, & Dale, 2019), indicating that additional measures focusing language development in the majority language should be taken already in preschool to reduce potential future inequalities in educational outcomes. For EF, there was no significant association to bi-/multilingualism in any of the current studies, in line with an increasing body of research refuting any bilingual advantage for EF.

7.1.2.5. Preschool attendance and quality

General aspects of preschool attendance, such as age at enrolment and the amount of time spent at preschool have received little attention, also from an international point of view. Potential links between the outcome measures and age at preschool start and the current time/week spent at preschool were investigated in all the current studies, but no significant results were found.

Preschool quality was rated with ECERS-3 during the intervention period in Study III, but no significant associations to language, EF or selective attention were found.

7.1.3. RQ 3. Effects of preschool interventions

Can preschool interventions improve language, EF and/or selective attention? The short answer, based on results from Study III, is no. There were no intervention effects. Children who either participated in group-based collaboration in the SEMLA intervention, or who took part in specific attention-enhancing exercises and individual math training in the DIL intervention did not improve their language, EF, attention or mathematics skills more than the control group. How can this lack of intervention effects be understood?

The simplest explanation is perhaps that the interventions did not differ sufficiently from regular preschool practices. In particular the group-based SEMLA intervention was conceptualized as a refined version of present pedagogical working methods. Since previous Swedish preschool research has not linked teachers' working methods or behavior to measurable outcomes in children, it is hard to say if SEMLA was different enough from business-as-usual.

For DIL, it seems intuitive that children who practice math several times a week, and who participate in activities specifically designed to target aspects of EF, could be expected to improve those skills (which they did not). For SEMLA on the other hand, the intervention was believed to enhance children's language by the participation in meaningful conversations about the learning object, and by the introduction of new words and concepts by the teachers. Such interactions hopefully take place in every preschool, regardless of intervention, but the knowledge base is lacking with respect to how current preschool practices affect children's language learning, since neither preschool teachers nor preschool researchers measure individual children's abilities.

SEMLA was expected to improve EF, including selective attention, by processes of verbally mediated reflection and focused attention, in combination with teacher scaffolding. This is based on theoretical models of EF that may not necessarily have empirical support. Also, the SEMLA teacher training may not have been sufficient to make the intervention sufficiently different – and better – than the typical preschool pedagogical practices.

Another problem, not discussed extensively in Study III, is the distance between hypothesized active intervention components and outcome measures, which may in turn be seen as reflecting the differing traditions with regard to methodology and how new knowledge is generated in the multidisciplinary research team behind the study.

As discussed in Study III, there is a range of complicating factors. To start with, groups differed at baseline on potentially important aspects such as age, SES and proportion of multilingual children. Another problematic issue is that the control group had significantly higher preschool quality than the intervention groups. Although all these aspects were controlled for statistically, it may still have influenced the intervention delivery or uptake.

Yet another problem was intervention fidelity. First of all, it was a challenge to find appropriate ways of capturing fidelity, since the two interventions were so different from one another. Second, the SEMLA intervention seemed difficult for preschool staff to execute. The number of sessions was lower than recommended and the quality of intervention varied between preschool units. It should be pointed out that preschool quality was generally high, whereas an intervention involving educating the teachers may be more powerful in preschools of lower quality. But to capture the above-mentioned, quite subtle aspects of teacher–child interactions, other, more qualitative tests and evaluation methods are needed. Future work should however ensure that it is exactly the interaction which is in focus, instead of focusing only on teachers, which seems to have been the case in previous work concerning language and literacy in preschool (see also Section 5.2.1).

To conduct an intervention study in Swedish preschools can be described as pioneering. In spite of the multitude of challenges, including the lack of effects, the mere fact that such a study could be conducted, in close collaboration with researchers from early childhood studies, must be declared as an achievement. An RCT including behavioral tests and quantitative statistical analysis has been accused of a number of shortcomings from the field of preschool didactics and early childhood studies, including that such research objectifies children, contributes to the neoliberal governance of society and represents an instrumental view of learning (see Frankenberg, 2018, for a summary). The possibility that this first intervention study in Swedish preschools has opened up the field for more interdisciplinary work to provide a solid scientific base for Swedish preschools, is perhaps one of the more important outcomes of Study III. As outlined in the previous sections in this chapter, future preschool interventions should target those who need it the most and future work should focus on how to identify those children and on finding and evaluating appropriate methods to provide equal opportunities for cognitive and social development in preschool.

7.2. The language–EF relationship revisited

To reveal the direction of the language–EF relationship, longitudinal work is needed, and clearly, the current studies do not contribute to the knowledge base in that regard. The current work should rather be viewed as laying the ground for some future endeavors. In chapter 2, I described the dynamic and emergent nature of development in general, including that what we refer to as language and EF seem to be subject to change, not only from the perspective of an individual's course of development, but also in the nature and underlying structure of the constructs themselves. In chapter 3, I outlined the diversity with regard to theories and models accounting for the nature of language and EF and the possible underpinnings of a language–EF association. Three very general models of the relationship between language and EF were also introduced, inspired by Bishop, Nation and Patterson (2014):

A. EF affects language functioning
B. Language functioning affects EF
C. A third factor, X, influences both EF and language

A theory of the language–EF relationship and the hypotheses generated by such a theory should preferably be able to disentangle whether or not language and EF rely on the same, domain-general mechanisms (in other words, Model C) or if there are to some extent specific language and EF processes. An important methodological aspect pointed out by, among others, Kaushanskaya et al. (2017), is the necessity of using non-verbal EF tasks to avoid the task impurity problem.

A review of earlier work reveals that it is still unclear whether executive functions are a better predictor of language skills or vice versa. As previously mentioned (Section 3.4.1.1), Rose, Feldman, and Jankowski (2009) found predictive relationships between cross-modal transfer and receptive vocabulary and verbal fluency. Concurrent relationships between short-term memory and language measures were however not significant at age 1. This is in contrast to studies of older children, which have shown the importance of phonological short-term memory for word learning (e.g. Gathercole et al., 1999). Findings by Friend and Bates (2014) indicate that the ability to maintain focus and inhibit prepotent responses at 4 years of age supports subsequent narrative ability, but also that narrative ability at age 4 predicted performance on an EF test of cognitive flexibility at age 5. On one hand, Slot and von Suchodoletz (2017) found that language was a better predictor of EF than vice versa, but their data also indicates a bidirectional relationship between language and EF in 3–4-year-olds. A proposal by Hughes and colleagues (2009) is that the relationship between verbal ability and EF performance is characterized by a threshold function, in parallel to the relationship between language skills and false belief understanding (Happé, 1995; see also Section 2.1.2), suggesting that a child needs a certain level of language ability to succeed on EF tests. Gains in language skill beyond the threshold level may have little impact.

Instead of merely concluding that previous results regarding the nature of the language–EF relationship are contradictory, an alternative explanation could be that language and EF affect each other in different ways at different points in development, a view that could be compatible with Model C – that both abilities are affected by some common underlying factor – or with the addition of a fourth model, Model D, arguing for a complex reciprocal relationship between language and EF and taking into account the complexity of the interplay between language and EF:

D. Language and EF have a reciprocal relationship, where the direction of the association may change over developmental time, depending on what aspect(s) that are the focus of interest, and of the context in which these aspects are investigated

If one adopts a view on development as dynamic, where change occurs within complex systems with multiple interactions (Dynamic Systems Theory; e.g. Thelen, 2001; see also Section 2.1 above), then simple notions of cause and effect are insufficient to explain development. Attempts to force previous results into either Model A or B may be oversimplifications. Model D is instead congruent with a theory of *mutualism*, so that separate abilities such as vocabulary, working memory etc. facilitate each other's growth through several distinct mechanisms (see Kievit, 2020, for a recent review).

Moreover, the current distinction between language and EF could to some extent be seen as artificial: If, as suggested by Gandolfi and Viterbori (2020), EF are necessary to create sentence representations, to select the right word and to inhibit the tendency to say something inappropriate, it can be argued that aspects of what we refer to as EF are in fact an intrinsic and obligatory part of language processing and use, including both the lexical, morphosyntactic and pragmatic domains. Also, as indicated by Borragan et al., (2018), there may be mechanisms currently labeled as inhibitory processes that are instead domain-specific for language, further challenging the way we currently tend to categorize and delimit language and EF. MacDonald and Christiansen (2002) questioned the mere existence of an isolated working memory capacity construct, and claimed instead that the distinction between verbal working memory and language processing tasks is artificial. In their view, deficits that are seen in performance on verbal memory tasks can be attributed to variations in exposure to similar language processing experiences and to neurobiological differences in processing accuracy such as variations in the ability to construct robust phonological, semantic, and syntactic representations (ibid.). Perhaps 'language' and 'EF' need to be reconceptualized more radically than previously thought.

7.3. Limitations

As mentioned, one of the clearest limitations of the current work is that the research design precludes any conclusions regarding the direction of the language–EF relationship. The choice of materials was mainly guided by requirements in Study III, that is, that tests and tasks should enable reliable measurement of potential intervention effects, rather than investigating the language–EF relationship. Completely non-verbal EF tests would have been preferable, as it would enable stronger claims about the relationship between domain-general cognitive capacities and language. Additionally, a reliable test of Theory of Mind/higher levels of intentionality would have been desirable. Yet, since the studies in the current thesis were among the first to examine links between language and EF in Swedish preschoolers, they can be seen as a point of departure for future work.

A composite measure of EF was used in all studies, and in Study III, a composite language measure was employed. The analytic strategy was defined and reported before data analysis (Gerholm et al., 2018), but in hindsight, these composite measures should preferably have been based on a factor analytical approach, not least since the dimensionality of language as well as EF in early childhood is debated (see also Section 2.2.1 and 2.3.1).

For Swedish AudAt, reported in Studies II–III, there was an element of self-selection in the sampling procedure, which may have led to a subsample that was not entirely representative of the full sample. A general methodological concern is that the reliability of ERP components is under-reported (Huffmeijer et al., 2014), and another potentially problematic issue is the lack of concurrent correlations between attention effect and behavioral measures of EF, whereas attention was (weakly) associated with language. If AudAt measures domain-general attentional capacities, or aspects of interference control, it is expected to show associations to both EF and to language. In the current data, that was not the case, leading to questions regarding the conceptualization of AudAt as a measure of self-regulation, in other words, EF, and consequently regarding the construct validity of Swedish AudAt.

Socioeconomic background had associations to outcome measures, but it is unclear how to best operationalize SES in the Swedish context. Furthermore, when it comes to comparing current results to other studies, it is unclear to what extent SES measures from different contexts are equivalent. For instance, educational level in Sweden does not reflect financial situation in the same way as in other contexts, since higher education is free of charge in Sweden. Perhaps aspects of cultural capital (see also Pajkin, 2014) or measures of parent–child interaction (see also Hoff, 2003) would be more informative than parental income and education. Another limitation related to SES was that both the small sample in Study I and the large sample in Studies II–IV were skewed toward higher SES and the preschools had generally high quality. Previous intervention studies in preschool have often aimed at at-risk children, for instance children from lower-SES backgrounds. Future work regarding the effects of specific preschool-based interventions as well as evaluation of ongoing pedagogical practices should focus on children at risk for difficulties.

In the current studies, we chose to include all children in preschool. If parents gave consent and children agreed to be tested, they were considered eligible. Such wide inclusionary criteria comes with some challenges: in the optimal case, multilingual children would be assessed for language in both/all their languages, this was however not practically possible given the large number of different languages spoken. Parental questionnaires were translated into Arabic and English, but ideally, materials should have been available in several, if not all, languages preferred by parents. Information regarding children's language situation, for instance amount of exposure for the languages, and potentially information regarding whether or not parents were born in Sweden or not would have been informative, but parental questionnaires were already extensive and such questions could be regarded as intrusive. The alternative, to exclude bi- and multilingual children would however lead to a sample which is not representative of the Swedish preschool population.

7.4. Future directions

Besides methodological improvements as outlined in the former section, there are some outstanding issues that need further work. These concern the dimensionality and developmental course of language in conjunction with EF, and the relation to advanced levels of shared intentionality and Theory of Mind. It is still not clear how these aspects of social and cognitive development may rely on one another, and future work should include the possibility that the language–EF relationship may be of a dynamic and reciprocal nature during the course of development. In line with Kievit's (2020) proposal, there is a need for multicenter, large-scale longitudinal studies as well as an increased formalization of theories into testable models.

Differences in language and EF abilities and development relating to SES and sex have not been sufficiently explored in the Swedish context and need further attention. The absence of significant links between behaviorally assessed EF and selective auditory attention measured with an ERP experiment warrants further investigation, in particular with regard to the lack of connection between selective auditory attention and interference control in the visual modality. It has been shown that auditory distractors are more difficult than visual distractors for young children in a visual selective attention experiment (e.g. Robinson, Hawthorn, & Rahman, 2018). Adults with dyslexia performed poorer on tasks of interference control in the auditory modality compared to visual interference suppression (Gabay, Gabay, Schiff, & Henik, 2020), potentially reflecting the long-term importance of auditory selective attention for abilities relating to language and literacy, in line with results by ten Braak et al. (2018), who showed that attentional control predicted phonological awareness in young school-aged children.

The implementation of an RCT in Swedish preschool in close collaboration with early childhood scholars as well as with educators, children and parents hopefully paves the way for similar, but perhaps more targeted preschool intervention studies in the future. The research question should inform the methodological considerations, instead of theoretical positions, ideologies or traditions. Swedish preschool reaches nearly all children and there are excellent opportunities to support development and learning during formative years, but more research is needed to find out how to reach the children that need intervention the most, and to reveal how to best educate preschool teachers to support children in the best way possible. Such work also includes increasing the knowledge regarding children that do not attend preschool. In the light of recent political suggestions to make preschool mandatory for certain groups specifically to improve language ability (SOU 2020:67), it seems even more vital to guarantee that Swedish preschool becomes evidence-based. EFss are important for life outcomes but the concept of EF or cognitive control is largely unknown to the general public and to early childhood educators. It does not seem unreasonable to include aspects of EF in the Swedish preschool curriculum, and it has been suggested that EF, together with language and socio-emotional development, should be regarded as core subjects in preschool (Bruce & Riddersporre, 2012).

7.5. Conclusion

The current studies provide evidence of a language–EF relationship in Swedish 4–6 -year-olds, with a possible specific association between grammar and inhibition/interference control, in line with previous work from other contexts. For selective auditory attention as measured with an ERP paradigm, associations to language were confirmed but not to behaviorally assessed EF. Future work is needed to reveal more about the association between selective auditory attention and language as well as clarifying possible effects of modality on interference suppression.

The nature, direction(s) and link(s) of the language–EF association during the course of development need further investigation, but given the complex dynamics of development, a reciprocal relationship between language and EF is suggested, and current descriptions of language and EF may be insufficient to capture the intertwined nature of the relationship.

The current work also provides support for a connection between socioeconomic background and cognitive development in Swedish preschoolers, indicating a need to specifically target children from lower-SES backgrounds in interventions to reduce inequalities present early in life. More research is needed to ensure an evidence-based preschool for all children, and to develop specific, efficient methods targeting those who need it the most.

8. Summary in Swedish

Introduktion

Språk och exekutiva funktioner (EF) hänger nära samman och båda områdena utvecklas radikalt under åren mellan födsel och skolstart. Tidigare forskning har klargjort att det finns kopplingar mellan språk och EF men exakt hur relationen ser ut är ännu oklart. När det gäller svenska förskolebarn finns det begränsad kunskap om kopplingen mellan språk och EF och om hur dessa förmågor kan förbättras via pedagogiska metoder och arbetssätt i förskolan. Målen med avhandlingen är att undersöka: i) hur språk och EF, inklusive selektiv auditiv uppmärksamhet, hänger ihop hos barn i åldern 4–6 år, ii) möjliga kopplingar till faktorer som hör ihop med barnet och hens omgivning och iii) om specificerade pedagogiska arbetssätt kan leda till stärkt förmåga vad gäller språk och exekutiva funktioner.

Avhandlingen har följande struktur: i kapitel 2 beskrivs utveckling av språk, EF och selektiv uppmärksamhet på ett övergripande plan och ett generellt synsätt på utveckling presenteras. Kapitel 3 ger en översikt av teorier om språk och EF och om möjliga kopplingar dem emellan. I kapitel 4 diskuteras en rad metodologiska utmaningar när det gäller att undersöka kopplingen mellan språk och EF och kapitlet innehåller också en översikt över de metoder och material som används i avhandlingens delstudier. Kapitel 5 beskriver svensk förskola och ger en kort översikt av svensk såväl som internationell förskoleforskning med fokus på de kunskapsluckor som finns när det gäller effekter av förskolevistelse i den svenska kontexten. Kapitel 6 sammanfattar avhandlingens delstudier och dessas bidrag till kunskapsläget och det avslutande kapitel 7 innehåller en övergripande diskussion och förslag på fortsatt forskning.

Metod

Alla tester och mätningar genomfördes på barnens förskolor i nära samarbete med pedagoger. För att få en bred bild av deltagarnas språk och EF användes en kombination av metoder: olika test, berättaruppgifter, skattningar baserade på videomaterial av interaktion mellan barnen och testledarna samt frågeformulär till föräldrar och förskolepersonal. Dessutom användes elektroencefalografi (EEG) för att registrera hjärnans respons och därigenom få ett mått på selektiv uppmärksamhetsförmåga. Jämfört med hjärnavbildningsmetoder är EEG icke-invasivt: elektroder fästs i en mössa som barnet har på sig. Det specifika experiment som användes i studierna har utvecklats av Neville med kollegor (Coch et al., 2005; Sanders et al., 2006) och är en barnvänlig variant av befintliga uppmärksamhetsexperiment för vuxna. Barnens uppgift är att lyssna på två sagor samtidigt, en i vänster och en i höger högtalare, och försöka fokusera på den ena sagan och strunta i den andra. Genom att jämföra hjärnans responser till den uppmärksammade och den ignorerade sagan får man fram ett uppmärksamhetsmått eller uppmärksamhetseffekt. Originalversionen av experimentet har visat sig kunna mäta stärkt uppmärksamhet efter intervention (Neville et al., 2013) och en anpassad svensk variant togs fram till de aktuella studierna.

Studier

Avhandlingen baseras på fyra delstudier. Studie 1 och 2 undersöker kopplingar mellan språk och EF, delstudie 3 undersöker effekter av förskoleinterventioner och studie 4 behandlar aspekter av barns berättarförmåga och eventuella associationer till EF, andra aspekter av språk samt bakgrundsfaktorer.

Delstudie 1 är en pilotstudie som undersöker kopplingen mellan språk och EF och eventuella kopplingar till bakgrundsfaktorer i ett urval av 47 barn. Delstudie 2 utvidgar studie 1 och undersöker samma frågeställningar i ett betydligt större urval av 431 barn och med tillägg av EEG-experimentet. Hypotesen var att tidigare rapporterade samband mellan språk och exekutiv förmåga skulle visa sig gälla också för svenska barn i åldern 4–6 år samt att det skulle finnas kopplingar till ålder och till barnens socioekonomiska bakgrund. Det antogs också att uppmärksamhetseffekten skulle ha ett samband med EF mätt med traditionella tester. Dessutom utforskades eventuella könsskillnader, eventuella skillnader mellan enspråkiga och flerspråkiga barn och huruvida förskolekvalitet och tid på förskolan hade någon betydelse för barnens språkförmåga och EF. I delstudie 3 undersöktes effekter av specifika förskoleinterventioner. Interventionsstudier i förskolan är mycket ovanliga i Sverige och ses av många som kontroversiella. SEMLA-interventionen innebar ett gruppbaserat arbetssätt med stor vikt vid interaktionen barn-barn och barn-pedagog, medan DIL var en kombination av individuell matematikträning via iPad och gruppövningar som syftade till att stärka barnens EF och uppmärksamhet. Interventionerna utformades av forskare inom förskoledidaktik. Delstudie 4 tittade närmare på en detalj i barnens narrativ, nämligen hur de gick tillväga för att förklara ett fiktivt missförstånd och i vilken mån detta hörde ihop med språkförmåga, EF och bakgrundsfaktorer.

Som förväntat visade resultaten att språk och EF har en koppling även hos svenska 4-6-åringar. I linje med tidigare studier verkar det finnas en mer specifik association mellan barnens grammatiska förmåga och inhibering, vilket utgör en av delkomponenterna i den exekutiva förmågan. Kopplingen till grammatik gällde också för selektiv uppmärksamhet. Det sistnämnda kan ses som en del av inhiberingsförmågan, nämligen förmågan att kunna ignorera irrelevanta stimuli. Barnens socioekonomiska bakgrund visade sig relatera både till språk, EF och uppmärksamhet. Vad gäller språkförmåga presterade flickor bättre än pojkar på ordförståelse och grammatik, i linje med en rad studier som tyder på starkare språklig förmåga hos flickor. De flerspråkiga barnen presterade lägre än enspråkiga vad gällde ordförståelse på svenska, även när man statistiskt kontrollerade för socioekonomisk status. Interventionerna i delstudie 3 ledde inte till mätbara förbättringar i språk, EF eller uppmärksamhet jämfört med kontrollgruppen.

Slutsatser

Det finns ett stort behov av fortsatta studier vad gäller förskolans arbetssätt, både på ett generellt plan och mer specifikt vad gäller mer riktade insatser. Tidig upptäckt och stöd till barn som är i riskzonen för att tidigt hamna på efterkälken när det gäller språk och EF är väsentligt, inte minst eftersom en rad studier visat på hur viktigt både språkförmåga och EF är för skolgång, arbetsliv och livskvalitet. Socioekonomisk bakgrund och dess påverkan på språklig och kognitiv utveckling behöver utforskas ytterligare i den svenska kontexten.

De aktuella studierna tyder på en specifik relation mellan aspekter av inhiberingsförmåga och grammatik, men kopplingarna mellan språk och EF behöver utforskas närmare. Teorier kring varför förmågorna hänger ihop behöver förfinas, men en preliminär slutsats är att språk och EF är oupplösligen förenade och tycks utöva ömsesidig påverkan på varandra under utvecklingens gång.

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