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THE RELATIONSHIP BETWEEN PRE-READING, LANGUAGE AND MEMORY SKILLS IN PRESCHOOL-AGED CHILDREN: A LONGITUDINAL STUDY

Linda Jansson
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Supervisor: Suvi Stolt
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Medicinska fakulteten

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Tekijä - Författare - Author
Linda Jansson

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Tiivistelmä - Referat - Abstract
Språkstörningar påverkar utvecklingen av barns kommunikationsförmåga. Tidig identifiering av barn som senare kan komma att diagnosticeras med språkstörning är utmanande, men den tidiga språkutvecklingen är en bra indikator på senare språkkunskaper. Språkets grundläggande strukturer är vanligtvis etablerade vid fem års ålder. Minnesförmågan, som är essentiell för språkutvecklingen, är också väl utvecklad hos femåriga barn. Läsförberedande färdigheter, så som snabb benämning och bokstavskännedom, utvecklas under hela barndomen och har kopplats till samtida språkkunskaper. Kunskapen om utvecklingen av läsförberedande färdigheter hos barn under fem års ålder är dock begränsad. I denna longitudinella studie studeras sambandet mellan läsförberedande färdigheter hos barn i åldrarna 3;6 och 5;0 år och språk- och minnesförmåga vid 5;0 års ålder. Ökad kunskap om utvecklingen av och förhållandet mellan läsförberedande färdigheter och språklig förmåga kan leda till utveckling av känsligare metoder för identifiering av barn som riskerar språkstörning.

I denna studie användes LUKIVA-testet, en metod för bedömning av läsförberedande färdigheter hos barn i förskoleåldern. Ytterligare användes språk- och minnesdomänerna från Fem till femton-frågeformuläret, ett föräldraformulär som utvärderar utveckling och beteende hos 5–15-åriga barn. LUKIVA-testet administrerades i åldrarna 3;6 och 5;0 år, Fem till femton-frågeformuläret fylldes i när barnen var 5;0 år gamla. I studien deltog 40 finsktalande barn.

Denna studie visade, att läsförberedande färdigheter vid 3;6 och 5;0 års ålder korrelerade signifikant med varandra och med språkförmågan i 5;0 års ålder. Ytterligare visades, att läsförberedande färdigheter vid 3;6 års ålder, tillsammans med kön och maternell utbildning, förklarar 17% av variationen i språkförmågan vid 5;0 års ålder. De läsförberedande färdigheterna hos 3;6-åriga barn kan således ge viktig information om framtida språkutveckling. Dessutom visades, att minnesförmågan (sr_i^2 = 43%) betydligt påverkade samtida läsförberedande färdigheters (sr_i^2 = 28%) förklaring av språkförmågan hos 5;0-åriga barn. Läsförberedande färdigheter kan eventuellt användas för att identifiera barn med svag språklig förmåga, vars språkliga utveckling kan vara i behov av stödåtgärder.

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Läsförberedande färdigheter, språkförmåga, språkutveckling, minnesförmåga, barn, förskoleålder

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Tiivistelmä - Referat - Abstract
Language impairments affect the development of children’s communication skills. Early identification of children that may later face a diagnosis of language disorder is challenging, but early language development is a good indicator of later language skills. The fundamental structures of language are typically mastered by the age of five. Memory skills, which are essential for language development, are also well developed in five-year-old children. Pre-reading skills, such as rapid automatized naming and letter knowledge, develop throughout childhood and have been linked to concurrent language skills. There is, however, little knowledge regarding early development of pre-reading skills in children under the age of five. In this longitudinal study, the relationship between early pre-reading skills at ages 3;6 and 5;0 and language and memory skills at age 5;0 is studied. By increasing the knowledge regarding the development of and the relationship between early pre-reading and language skills more sensitive methods to identify children at risk for language impairment may be developed.

In this study, the LUKIVA-test, a method for assessing early pre-reading skills in preschool children, was used. In addition, the language and memory domains of the Five to Fifteen-questionnaire, a parental questionnaire evaluating the development and behavior of 5–15-year-old children, was used. The LUKIVA-test was administered at ages 3;6 and 5;0, the Five to Fifteen-questionnaire filled out when the children were 5;0-years old. The study sample included 40 Finnish-speaking children.

This study showed, that age 3;6 and 5;0 LUKIVA-test variables correlated significantly with each other and with age 5;0 language skills. It was also shown, that pre-reading skills at age 3;6, together with gender and maternal education, explain 17% of the variability in language skills at age 5;0. Pre-reading skills in 3;6-year-old children may thus yield important information regarding future language development. In addition, memory skills ($sr_i^2 = 43\%$) markedly added to the explanation of age 5;0 language skills by concurrent pre-reading skills ($sr_i^2 = 28\%$). Pre-reading skills may possibly be used to identify children with weak language skills, whose language development may benefit from additional support.

Avainsanat - Nyckelord

Keywords
Pre-reading skills, language skills, language development, memory, preschool-aged, children

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1 INTRODUCTION

Language development requires proficiency in a range of linguistic and cognitive skills (Kuczai, 1999). Language acquisition exhibits wide variation, but by the age of five children have typically mastered the fundamental structures of language as well as basic knowledge of language use (Baird, 2008). Memory skills, which are essential for language acquisition, are also quite well developed in five-year-old children (Alloway, Gathercole & Pickering, 2006). In addition, pre-reading skills such as rapid automatized naming and letter knowledge have been linked to concurrent language skills in five-year-old children and to literacy skills throughout childhood (e.g. Adlof, Catts & Lee, 2010; Caravolas et al., 2012; Papadimitriou & Vlachos, 2014). There is, however, little knowledge regarding the early development of pre-reading skills in children under the age of five.

Language impairments affect the development of communication skills. Weak language skills may result in secondary problems, which can affect academic achievement and future employment and cause emotional and behavioral problems. While the language skills of some children whose language development is delayed may improve spontaneously, some children are diagnosed with language disorder. Early identification of children that will later be diagnosed with language disorder is challenging. Early childhood language development is, however, a good indicator of language development in later childhood (Rescorla & Dale, 2013). Identification of factors in early childhood language development that may aid in early identification of children at risk for language impairment is important. Such early factors may include pre-reading skills. Early identification of at-risk children would allow measures of early intervention to be administered. Early intervention might attenuate later problems or even prevent problems from emerging.

In this longitudinal study, the relationship between early pre-reading skills at ages 3;6 and 5;0 and language and memory skills at age 5;0 is studied. Although 3;6 years is a very early age for evaluation of pre-reading skills, these skills have been shown to be developmentally stable in older preschool-aged children (Ozernoz-Palchik et al., 2017; Puolakanaho et al., 2008). In this thesis, the term *preschool-aged* refers to children age 2–7 who have not yet started school.

2 DEVELOPMENT OF PRE-READING SKILLS

In preschool-aged children, the mastering of certain pre-reading skills has been linked to concurrent language skills. These skills include rapid automatized naming (RAN) and letter knowledge (e.g. Adlof et al., 2010; Caravolas et al., 2012; Papadimitriou & Vlachos, 2014). In addition to pre-reading skills, familial risk for dyslexia has been linked to childhood language development and language impairment (Newbury et al., 2011). Development of RAN and letter knowledge in preschool-aged children, as well as familial risk for dyslexia, in relation to language development are the focus of the present study.

2.1 Rapid automatized naming

Rapid automatized naming is the ability to quickly name a set of visually presented familiar items aloud (Kirby, Georgiou, Martinussen & Parrila, 2010). What RAN as a skill encompasses is, however, still open to debate. Rapid automatized naming has, for example, been considered a phonological skill (Gombert, 1992; Melby-Lervåg, Lyster & Hulme, 2012). Rapid automatized naming can be regarded as an implicit skill, i.e. a skill that is unconsciously and automatically engaged. Phonological awareness, in contrast, is an explicit skill, which entails conscious and intentional manipulation of phonemes. A connection between RAN and access to mental representations of phonological constructs stored in long-term memory has been suggested (Kirby et al., 2010 citing Torgesen et al., 1994, 1997). Others have suggested a link between RAN and attention and between RAN and articulation of presented items (Georgiou, Parrila & Kirby, 2006; Jones, Obregón, Kelly & Branigan, 2008). Rapid automatized naming may also measure the ability to link visual and verbal modalities in memory or reflect a general cross-modal learning mechanism (Hulme & Snowling, 2013; Kirby et al., 2010 citing Wiens, 2005). Rapid automatized naming skill could also reflect cognitive processing speed or working memory skills (Amtmann, Abbott, & Berninger, 2007; Kail, Hall & Caskey, 1999).

To test RAN individuals are asked to name familiar items presented in a group, such as letters, digits, objects or colors, as fast as they can (Hulme & Snowling, 2013). The use of objects or colors is necessary for children, who have not yet mastered knowledge of letters or digits well enough to be used in this test. Rapid automatized naming is often considered a unitary skill (Georgiou et al., 2006). Thus, when RAN is measured total performance time is recorded. Total performance time of RAN can, however, be broken down into pause time and articulation time, which reflect attention and inhibition and mobilization of articulatory functions, respectively (Clarke, Hulme & Snowling, 2005; Georgiou et al., 2006; Lervåg & Hulme, 2009; Neuhaus & Swank, 2002; Parrila, Kirby & McQuarrie, 2004). Individual variations in total performance time is mainly reflected by variations in pause time (Georgiou et al., 2006). Articulation time show minimal developmental changes. According to Georgiou and coworkers (2006), the benefits of measuring pause time is, however, overweighed by the technically much easier task of measuring total performance time. Total performance time has thus been considered an adequate reflection of RAN skill.

Rapid automatized naming in children under the age of five has not been studied extensively. There is thus little knowledge available regarding the development of RAN in young children. Puolakanaho and coworkers (2007) did, however, measure RAN in 3;6- and 5;6-year-old Finnish-speaking children in a study focusing on evaluating the risk of future reading disability for individual children. The test battery of Puolakanaho and coworkers (2007) did not include RAN measures at age 4;6, which would have allowed a more detailed analysis of the longitudinal development of RAN in preschool-aged children. A predictive model of the development of RAN at ages 3;0, 3;6, 4;0, 4;6, 5;0 and 5;6 was, however, built in the development of the LUKIVA-test, which is a method for assessing pre-reading skills in preschool children (Puolakanaho, Poikkeus, Ahonen & Aro, 2011). Rapid automatized naming has been studied in more detail in older children. Rapid automatized naming was shown by Lepola, Poskiparta, Laakkonen and Niemi (2005) to be developmentally stable in Finnish-speaking 5–7-year-old children. This means that the skill level, i.e. RAN performance time, early in development corresponds to the skill level later in development. Rapid automatized naming is developmentally stable also in English-speaking 5–7-year-old children (Ozernoz-Palchik et al., 2017).

Rapid automatized naming and its relation to concurrent language and memory skills has been studied to some extent in preschool-aged children. Adlof and colleagues (2010) studied RAN in English-speaking five-year-old children and found that faster RAN was associated with better receptive and expressive language skills. Faster RAN also correlated with better narrative skills. Caravolas and coworkers (2012) showed, that faster RAN was associated with better vocabulary knowledge, as measured using the Wechsler Preschool and Primary Scale of Intelligence (WPPSI)-III vocabulary subtest, in five-year-old English-, Spanish-, Czech- and Slovak-speaking children. Papadimitriou and Vlachos (2014), in turn, demonstrated, that faster RAN correlated with greater receptive and expressive vocabulary in 5–6-year-old (average age: 5.6 years) Greek-speaking children. Faster RAN has thus been associated with better vocabulary knowledge. Rapid automatized naming has also been associated with short-term memory. Papadimitriou and Vlachos (2014) and Caravolas and coworkers (2012) found, that faster RAN correlated with better verbal, or phonological, short-term memory in all languages studied (Greek, English, Spanish, Czech, Slovak). Slow performance in RAN has, in turn, been linked to developmental language disorder (Aguilar-Mediavilla, Buil-Legaz, Pérez-Castelló, Rigo-Carratalá & Adrover-Roig, 2014; Vandewalle, Boets, Chesquière & Zink, 2010; Waber, Wolff, Forbes & Weiler, 2000). The results presented above suggest, that faster RAN is linked to better language and memory skills in five-year-old children.

As presented above, RAN has been shown to be developmentally stable in 5–7-year-old children and associated with concurrent language and memory skills in five-year-old children. How RAN relates to concurrent or future language skills in preschool children under the age of five has not, to my knowledge, been studied. Thus, whether RAN is developmentally stable from an even earlier age than five and whether RAN in 3;6-year-old children is associated with future language and memory skills are questions that this study tries to answer.

2.2 Letter knowledge

Letter knowledge refers to the ability to recognize individual letters of the alphabet (Adlof et al., 2010). Letter knowledge combines visual and phonological modalities and entails the understanding of the alphabetic principle, i.e. how printed letters map on to phonemes of spoken words (Byrne & Fielding-Barnsley, 1989). While letter knowledge is not considered a phonological skill *per se*, phonologic awareness is necessary to create the mappings between graphemes and phonemes (Byrne & Fielding-Barnsley, 1989; Kenner, Terry, Friehling & Namy, 2017). Letter knowledge and phonological awareness are thus closely intertwined. Letter knowledge and phonological awareness show strong positive correlation in preschool children between the ages of two and seven, with letter knowledge predicting phonological awareness and phonological awareness predicting letter knowledge (Caravolas et al., 2012; Lepola et al., 2005; Lonigan, Burgess & Anthony, 2000; Molfese et al., 2006; Puolakanaho et al., 2008; Roth, Speece & Cooper, 2002). Torppa, Poikkeus, Laakso, Eklund and Lyytinen (2006) studied letter knowledge in 4;6–6;6-year-old Finnish-speaking children with and without familial risk for dyslexia. Using a stepwise logistic regression model the authors found, that weak phonological awareness and less teaching of letters at home predicted delayed letter learning for the group of children with familial risk for dyslexia. For children without familial risk for dyslexia slow RAN together with weak verbal memory, less teaching of letters at home and lower maternal education predicted delayed learning of letters.

Letters are not learned by random. Some letters are learned more easily than others (Justice, Pence, Bowles & Wiggins, 2006; Phillips, Piasta, Anthony, Lonigan & Prancis, 2012). Especially letters occurring in the child's name are better known to the child than other letters of the alphabet. Phillips and colleagues (2012) concluded, that the first letter in the child's name is the most likely letter to be known by the child, regardless of which letter it is. In their sample of 2–5-year-old English-speaking children, with most children being age four or five, the children could correctly name on average 60% of 26 presented letters. Unfortunately, data on mean letter knowledge at each age, which would have allowed for an analysis of longitudinal development of letter knowledge in English-speaking preschool-aged children, was not presented in the paper by Phillips and colleagues (2012). Puolakanaho and coworkers (2007, 2011) studied letter knowledge in 3;6-, 4;6- and 5;6-year-old Finnish-speaking children. Based on the data from 3;6-, 4;6- and 5;6-year-old children a predictive model of the development of letter knowledge was built in the development of the LUKIVA-test using linear estimation. Thus, the results estimate letter knowledge at ages 4;0 and 5;0 in Finnish-speaking children. Puolakanaho and colleagues (2007) have also shown, using logistic regression, that familial risk for dyslexia together with letter knowledge, RAN performance time and phonological awareness in preschool-aged children can be used to distinguish between children with and without risk for future reading disability in 2nd grade. Torppa and coworkers (2006), in turn, reported, that children correctly named on average 34% of 23 presented letters at age 4;6 and 45% of 23 presented letters at age 5;0. Thus, Finnish-speaking children aged 4;6 and 5;0 could name on average fewer letters than children in the English-speaking sample. This might be due to the fact, that formal teaching of letters is not introduced until pre-primary school, when children are on average six years old, in Finland. In English-speaking countries, formal teaching of letters might start earlier due to orthographic differences of the two languages, with Finnish having a regular orthography and English having a highly irregular and thus more complicated orthography (Aro & Wimmer, 2003).

Letter knowledge in preschool-aged children has been shown to be developmentally stable and at age five letter knowledge correlates positively with language skills (Adlof et al., 2010; Lonigan et al., 2000; Ozernoz-Palchik et al., 2017). Letter knowledge has also been shown to be positively associated with narrative skills in five-year-old English-speaking children (Adlof et al., 2010). In addition, better letter knowledge was associated with better vocabulary knowledge (WPPSI-III vocabulary subtest) in 5–6-year-old English-, Spanish-, Czech- and Slovak-speaking children (Caravolas et al., 2012). Caravolas and colleagues (2012) also found, that increased letter knowledge was associated with faster RAN and better verbal short-term memory skills. In children with developmental language disorder, letter knowledge has been shown to be delayed (Cordewener, Bosman & Verhoeven, 2012).

To my knowledge, the relationship between letter knowledge in 3;6-year-old children and concurrent and future language skills has not been studied. Determining how letter knowledge in young preschool children is associated with language skills is therefore important.

2.3 Familial risk for dyslexia

Dyslexia, a specific learning disability with neurobiological origin, is primarily associated with deficits in phonological skills, such as RAN and phonological awareness (Lyon, Shaywitz & Shaywitz, 2003). It is a multigenetic impairment where family history is an important risk factor (Kere, 2014). According to Shaywitz, Gruen and Shaywitz (2007), the risk that a child will have dyslexia is 40% if a sibling presents with dyslexia and 65% if a parent presents with dyslexia.

Dyslexia can be diagnosed only after the child is expected to have mastered reading and writing skills. Preschool-aged children at risk for reading impairment do, however, present with weaker pre-reading and receptive and expressive language skills than do children without risk for reading impairment (Bishop & Snowling, 2004; Lyytinen et al., 2004; McArthur, Hogben, Edwards, Heath & Mengler, 2000; Torppa, Lyytinen, Erskine, Eklund & Lyytinen, 2010). At least some of the children at risk for dyslexia may thus be identified before formal reading instruction begins by evaluating their pre-reading and receptive and expressive language skills.

Dyslexia is characterized mainly by impairments in phonological processing (Snowling, Bishop & Stothard, 2000). Children with delayed or impaired language development also experience deficits in phonological processing, including pre-reading skills, in addition to deficits within wider areas of language development, such as weakness in lexical learning and persistent grammatical difficulties (Bishop & Snowling, 2004; Snowling et al, 2000). Children at risk for dyslexia as well as children at risk for language impairment may thus present with deficits in pre-reading skills in addition to deficits in other language skills. Dyslexia and developmental language disorder are, in fact, highly co-morbid (McArthur et al., 2000). Around 50% of children with developmental language disorder also present with impaired reading skills.

3 LANGUAGE AND MEMORY SKILLS IN FIVE-YEAR-OLD CHILDREN

Language development requires a range of linguistic and cognitive skills, which are closely connected and influence each other (Kuczai, 1999). Speech and language acquisition is a complex process that exhibits wide variation. By the age of five a child has typically mastered the fundamental structures of language (vocabulary, phonology, morphology, syntax) (Baird, 2008). Five-year-old children have also acquired some knowledge regarding the pragmatic use of language. Language learning is heavily dependent on memory (Gillam, Montgomery & Gillam, 2009).

3.1 Language skills at age five

The acquisition of vocabulary entails linking of the linguistic symbol (i.e. words) with the correct semantic content. Early lexical acquisition exhibits great individual variation but by the age of five the size of the lexicon is roughly 11 000 words (Clark, 2009). Vocabulary is the part of language that develops the most after the preschool years, being at most 25% of that of an adult person's vocabulary in five-year-old children. By the age of five the relative use of different word classes is almost equal to that of adults (Dromi, 1999; Lyytinen, 2003; Masterson, Druks & Gallienne, 2008). Word-retrieval and naming of items include retrieval of semantic representations from the mental lexicon in long-term memory, activation of the right target word, selection and activation of the phonological representation of the target in the phonological output lexicon, and articulation (Friedmann, Biran & Dotan, 2013; Levelt, Roelofs & Meyer, 1999). Five-year-old children are already quite fluent in naming, a task that requires access to and strategic search of the mental lexicon (D'Amico, Devescovi & Bates, 2001; Kavé & Knafo-Noam, 2015; Troyer, Moscovitch & Winocur, 1997).

The development of vocabulary is linked to concurrent receptive and expressive language skills (Lepola, Lynch, Laakkonen, Silvén & Niemi, 2012; Lyytinen & Lyytinen, 2004; Potocki, Ecalle & Magnan, 2013; Roth et al., 2002; Silvén, Poskiparta & Niemi, 2004; Stolt, Haataja, Lapinleimu & Lehtonen, 2008). Florit, Roch, Altoé and Levorato (2009) demonstrated, that receptive vocabulary knowledge at age five was positively associated with listening comprehension. In another study it was found, that sentence comprehension and morphological and syntactic knowledge have important roles in listening comprehension in addition to receptive and expressive vocabulary knowledge (Florit, Roch & Levorato, 2013). According to Korpilahti (2012), comprehension skills of five-year-old children are still immature in several ways and complex language hampers comprehension. The study by Florit and coworkers (2009) also demonstrated, that listening comprehension is still developing at this age.

The development of phonology starts with the production of the very first words during the first or second year of life and is linked to development of vocabulary, morphology and syntax (Fenson et al., 1994; Ingram, 1999; Kuczai, 1999; Kunnari, Savinainen-Makkonen & Paavola, 2006; Stolt et al., 2008; Storkel & Morrisette, 2002; Torvelainen, 2007). At five years of age most Finnish-speaking children produce all the phonemes of the Finnish language (Kunnari, Savinainen-Makkonen & Saaristo-Helin, 2012). /S/ and especially /r/ are still often produced phonetically incorrectly as these speech sounds are motorically challenging (Savinainen-Makkonen & Kunnari, 2012). Combinations of consonants containing /r/ might also be difficult for some children.

Morphology refers to the grammar of words, typically plural markers of nouns, noun inflection and verb inflection (Karlsson, 1994). The acquisition of morphology is closely associated with the acquisition of the early expressive lexicon, at least in the early stages of development (Kuczai, 1977; Lyytinen, 2003; Stolt, Haataja, Lapinleimu & Lehtonen, 2009). Morphological development occurs predominantly before the age of five. By this age, children acquiring different languages have typically mastered around 80% of the inflectional system of their language (Ud Deen, 2009). The Finnish language has a complex grammatical structure with a striking total of fifteen noun cases (Karlsson, 1994). The Finnish verb inflection system is also abundant, with verbs being inflected by person, mood, tense and voice. Finnish is a mainly agglutinating language, with grammatical categories being added to words to give them their correct meaning. Single phonemes may change the meaning of a word and thus mastery of noun cases and inflectional morphology is critical for learning Finnish grammar. Morphophonological changes in the word stem may also occur when attaching an inflection. Mastering Finnish morphology is thus a challenging task. One might think, that children acquiring inflectionally rich languages may require longer to master the full grammatical structure of the language than children acquiring a grammatically less complex language, like English. It has, however, been concluded, that the morphological structure of complex languages is, in fact, acquired earlier (Ud Deen, 2009). Indeed, five-year-old Finnish-speaking children have usually mastered the basic rules of morphological inflection, with word formation and inflection being structurally compartmentalized, resembling closely the morphology of adult language (Bittner, Dressler & Kilani-Schoch, 2003; Lyytinen, 1982, 2003). Five-year-old Finnish-speaking children do still, to some extent, struggle with combinations and exceptions of the basic rules of inflection (Lyytinen, 2003). Abundant use of incorrect morphological inflections at age five is, however, a sign of atypical morphological development. Delayed acquisition of morphology has been associated with developmental language disorder (Rice, Tomblin, Hoffman, Richman & Marquis, 2004).

Syntax deals with the relationship between words, i.e. the structure of sentences, including principles governing order and interpretation of morphemes in a sentence (Karlsson, 1994). Morphology and syntax thus interact closely with each other. The acquisition of syntax starts when children start to produce word combinations around the age of two (Clark, 2009). Acquisition of complex syntax as well as temporal and causal relations and conditional constructs occurs when the child is around three years old. Children have typically mastered the rules dictating the use of syntax by the age of five (Kuczai, 1999).

Pragmatic skills refer to the ability to understand and use language appropriately in different social contexts (Baird, 2008; Loukusa, Paavola & Leiwo, 2011). Pragmatic skills include the use of non-verbal communicative signals, such as gestures and facial expressions, in addition to verbal communication. Theory of mind, i.e. the ability to understand the mental states of others, is important for the development of pragmatic skills (Baron-Cohen, 2000). Pragmatic difficulties have been associated with autism spectrum disorder, attention deficit hyperactivity disorder, and developmental language disorder (e.g. Lohmann, Tomasello & Meyer, 2005; Loukusa & Moilanen, 2009; Miller, 2006; Ryder, Leinonen & Schulz, 2008; Väisänen, Loukusa, Moilanen & Yliherva, 2014). The development of theory of mind and pragmatic language occurs actively when children are 3–6 years old, but continues for many years still (Loukusa, Leinonen & Ryder, 2007; Loukusa & Leinonen, 2008; Loukusa, Mäkinen, Gabbatore, Laukkanen-Nevala & Leinonen, 2017; Miller, 2006; Wellman, Cross & Watson, 2001). Pragmatic comprehension is already quite well developed in five-year-old children, especially in simple and familiar settings (Loukusa et al., 2007; Loukusa & Leinonen, 2008; Loukusa, Ryder & Leinonen, 2008; Miller, 2006; Wellman et al., 2001). Basic rules of conversation, like turn-taking, is also learned by the age of five (Clark, 2009; Kuczai, 1999).

Five-year-old children already have a wide knowledge base and can combine different knowledge in logical narrations (Griffin, Hemphill, Camp & Wolf, 2004). Narrations of five-year-old children are still limited in many ways, but the cognitive-linguistic development of narration is strong in 3–6-year-old children and five-year-old children narrate past, current and coming events (Becker Bryant, 2009; Berman & Slobin, 1994; Lyytinen, 2003; Mäkinen, Loukusa, Nieminen, Leinonen & Kunnari, 2014; Price, Roberts & Jackson, 2006; Schneider, Hayward & Dubé, 2006). The individual variation in narrative skills is quite large at this age due to differences in the structures of narrations and variations in linguistic skills (Berman & Slobin, 1994; Mertanen & Vaarma, 2015).

3.2 Memory skills at age five

Memory is essential for language development and learning. Short-term memory enables us to keep in mind what our senses are telling us (Baddeley, 2017). Working memory allows manipulation of this information, functioning as a link between cognition and action. Long-term memory refers to the basically limitless amount of information that can be stored and remembered (Ward, 2015).

Short-term memory involves temporary storage of information (Archibald & Gathercole, 2006). There is no significant processing of information in short-term memory. According to Baddeley (1986, 2003), verbal short-term memory is a temporary storage site for verbal information.

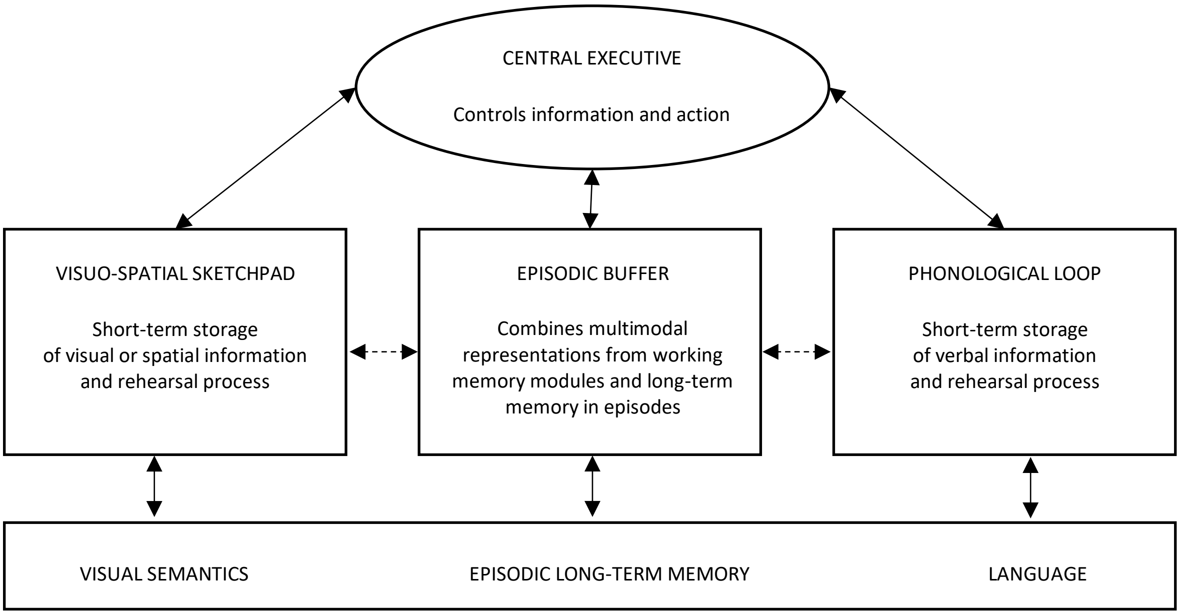

Figure 1. Baddeley's multicomponent working memory model. Adapted from Baddeley (2010).

There are several models of working memory. A well-known multicomponent model, presented in Figure 1, divides working memory into four modules: the *central executive*, the *phonological loop*, the *visuo-spatial sketchpad*, and the *episodic buffer* (Baddeley, 1986, 2003). The central executive is the module that controls information and action. It has limited capacity of attention and lacks storage capacity. It is important for the development of metacognitive language skills, i.e. awareness and management of an individual's own language skills, and planning and organization. Temporary storage and processing of verbal information and of visual and spatial information occurs in the two storage modules, known as the phonological loop and the visuo-spatial sketchpad, respectively (Baddeley, 2003). The phonological loop is of great importance for language development (Baddeley, 2003; Baddeley, Gathercole & Papagno, 1998). The phonological loop consists of two units, a phonological store for short-term storage of verbal information and a rehearsal process to keep the information active in memory to prevent forgetting. The phonological loop is assumed to be linked to language acquisition and long-term memory aspects of language (Baddeley, 2017). The visuo-spatial sketchpad, in turn, consists of a short-term store of visual or spatial information. The visuo-spatial sketchpad also contains a rehearsal process, allowing sustained attention to the item in question and prevention of forgetting. The visuo-spatial sketchpad is linked to visual semantics (Baddeley, 2010). Finally, the episodic buffer allows the other working memory modules to interact with each other (Baddeley, 2000, 2003). The episodic buffer has some storage capacity and can hold a limited amount of multimodal representations. The episodic buffer binds representations from other working memory modules and long-term memory together in episodes while making them available for conscious awareness.

Short-term memory and the four modules of working memory are established by the age of four (Alloway et al., 2006). The capacity of these memory systems grows with age and the relationship between short-term memory and working memory constructs have been shown to be developmentally stable in 4–11-year-old children (Alloway et al., 2006).

Both verbal short-term memory and verbal working memory are important for language development. Many children with language impairment have weak verbal short-term memory and verbal working memory skills, which may influence both receptive and expressive language skills (Adams & Gathercole, 1996; Alloway & Archibald, 2008; Archibald & Gathercole, 2006; Hoffman & Gillam, 2004; Majerus et al., 2009; Majerus, Poncelet, Greffe & Van der Linden, 2006). Baddeley and colleagues (1998) have suggested, that verbal short-term memory is especially important for mastering the phonological structure of language and establishing phonological representations in long-term memory. At age five, vocabulary knowledge correlates strongly and positively with verbal short-term memory skills (Gathercole & Baddeley, 1989; Florit et al., 2009; Lepola et al., 2012; Potocki et al., 2013). Both verbal short-term memory and verbal working memory contribute to language comprehension in five-year-old children. Verhagen and Leseman (2016) studied receptive vocabulary and grammar in five-year-old Dutch-speaking children. The authors concluded, using structural equation modeling, that receptive vocabulary and morphological and syntactical skills were predicted by concurrent verbal short-time memory skills. Verbal working memory skills predicted only acquisition of grammar, not receptive vocabulary.

The content of long-term memory increases as children encounter items to be stored (Pickering, 2001). Long-term memory has almost limitless capacity, but all stored information may not be consciously accessible (Ward, 2015). Memories that can be consciously accessed are called declarative memories while those that are not consciously accessible are called non-declarative memories (Squire, 2004; Squire, Knowlton & Musen, 1993). Declarative memory includes episodic memory (autobiographic events) and semantic memory (conceptually based world knowledge). Non-declarative memory includes procedural memory, classical conditioning, priming, and non-associative learning (Squire et al., 1993).

Preschool-aged children already have good long-term memory and can recall events that have occurred over a year ago (Peterson, 2002). Long-term memory skills have been linked to language skills, especially to narrative skills (Fivush, 2011; Nelson, 1993; Peterson, 2002). The capacity of verbal short-term memory affects coding in long-term memory. (Decker, Roberts & Englund, 2013; Gathercole & Baddeley, 1990). Memory retrieval, i.e. access to mental representations of the item in question, has been shown to be positively associated with RAN performance time in five-year-old children (Decker et al., 2013).

4 AIMS OF THE STUDY

The main goal of this thesis is to study the possible relationship between pre-reading and language and memory skills in preschool-aged children. The specific research questions are as follows:

1. Is there an association between pre-reading skills measured using LUKIVA-index (RAN, letter knowledge, familial risk for dyslexia) at ages 3;6 and 5;0 and language and memory skills measured at age 5;0?

2. How much of the language skills at age 5;0 can be explained by LUKIVA-index measured at age 3;6?

3. How much predictive value do memory skills measured at age 5;0 add to the possible relationship between language skills and LUKIVA-index measured at the same age?

This study is part of the Norming study of the Finnish short form version of the MacArthur Scale of Communicative Development Inventories – The Sanaseula Study (principal investigator: Dr. Suvi Stolt).

5 PARTICIPANTS AND METHODS

5.1 Participants

The study sample included 40 healthy full-term (born ≥ 37 gestational weeks) children (20 boys, 20 girls) of Finnish-speaking healthy parents. The children did not have a diagnosis of or suspected hearing impairment, cognitive developmental delay, autism spectrum disorder or cerebral palsy when asked to join the study. Exclusion criteria were parents' use of alcohol or illicit drugs or mental health problems, that the health clinic staff was aware of. The health clinic staff at child health clinics in Turku informed the parents about the study and provided them with a consent form in conjunction with the child's eight-month clinic appointment. Language development of all children was followed in a longitudinal study from eight months to five years of age during 2011–2017. In this thesis data collected at ages 3;6 and 5;0 was utilized. The data was gathered by MA Vehkavuori, MA Aalto, BA Simula and BA Lehto.

5.2 Methods

5.2.1 Design and procedure

The methods used in the present study were the LUKIVA-test (Puolakanaho et al., 2011) and the Five to Fifteen (FTF) parental questionnaire (Korkman et al., 2004b). The LUKIVA-test was administered to the children by a speech and language therapist or by students of logopedics. The test was administered at ages 3;6 and 5;0 years (≤ + two weeks from the targeted age). The data for the FTF for children at age 5;0 (≤ + two weeks from the targeted age) was collected in conjunction with evaluation of speech and language skills at age 5;0. The questionnaire was mailed to the parents prior to evaluation and returned to the research group during the evaluation.

The LUKIVA-test is a sensitive screening method for assessing early pre-reading skills in 3;6–5;6-year-old children and for identifying children at risk for future reading disability (Puolakanaho et al., 2011). The test is based on three key factors, which are RAN, letter knowledge, and familial risk for dyslexia (Puolakanaho et al., 2007; 2011). The LUKIVA-test is administered in an undisturbed room and takes approximately five minutes to complete (Puolakanaho et al., 2011). First, the child is shown a picture containing 30 familiar items (car, house, fish, pen, ball). The child is asked to name the items as fast as possible. Performance time (in seconds) is noted. The allotted time is 20–180 seconds. Second, the child is asked to name 23 letters of the alphabet one by one (A, B, D, E, F, G, H, I, J, K, L, M, N, O, P, R, S, T, U, V, Y, Ä, Ö). The child is given 1 point for each correct answer (max. 23 points). Third, familial risk for dyslexia is calculated based on information provided by the parents. The questionnaire is divided into two parts, part A and B. In part A of the questionnaire information regarding reading difficulties of the biological mother and the biological father is gathered. Reading difficulties are scored as follows: no difficulties – 0 points; difficulties in school – 1 point; difficulties throughout life – 1 point; don't know – 0 points. Part A yields a total of 0–4 points with a maximum of 2 points per parent. In part B of the questionnaire information regarding reading difficulties of the child's siblings, the mother's siblings or parents, and the father's siblings or parents is gathered. Reading difficulties are scored as follows: no difficulties for anyone – 0 points; at least one has had difficulties – 1 point; don't know – 0 points. Part B yields 0–3 points with a maximum of 1 point per group (sibling, mother's sibling or parent, father's sibling or parent). Familial risk for dyslexia is present if part A and part B of the questionnaire yields at least 1 point each.

Based on data from the Jyväskylä Longitudinal Study of Dyslexia, prediction models have been calculated for the age groups 3;6, 4;0, 4;6, 5;0, and 5;6 years. Data regarding RAN, letter knowledge and familial risk for dyslexia is entered to an online calculation program (http://www.nmi.fi/lukiva/indeksilaskuri) or the calculation program supplied on a compact disc. A mathematical equation calculates the child's predicted literacy, or index for reading ability, i.e. LUKIVA-index. Inversely, the same index illustrates the probability, that the child will face reading difficulties in the future. The index range is 1–100. Most children (ca 80%) will have a LUKIVA-index of 1–20, which corresponds to age-appropriate pre-reading skills. These children only have a small risk of facing severe reading disability in school. The rest of the children (ca 20%) will have a LUKIVA-index of 21–100, which corresponds to risk for reading disability in school. The calculation program interprets the results and the online version also visualizes the result using a graph.

The norms for the LUKIVA-test are based on 198 children, followed from birth to the end of 3rd grade, that participated in the Jyväskylä Longitudinal Study of Dyslexia (Puolakanaho et al., 2007; 2011). The LUKIVA-test allows for identification of children with the weakest early pre-reading skills at a specific age. Based on the assumption, that ca 12% of Finnish children present with dyslexia and that half of these (6%) have a familial risk for dyslexia, limits have been set to identify children in need of support (Puolakanaho et al., 2011). The LUKIVA-test identifies 65% of the children that will face problems in learning to read. The sensitivity of the test is thus ca 65%, with an accuracy of ca 85%.

Five to Fifteen, known in Finland as ViiVi, is a parental questionnaire evaluating the development and behavior of 5–15-year-old children and adolescents (5–15, n.d.; Korkman et al., 2004b). The questionnaire was developed by clinicians in the Nordic countries to be used as an instrument for examining behavioral, developmental and psychiatric problems of children and adolescents. The questionnaire consists of a total of 181 items covering eight domains and 22 subdomains. In this study, where language and memory were examined, the language and memory domains of the FTF were utilized. The language domain includes the subdomains of language comprehension (5 items), expressive language skills (13 items), and communication (3 items). Total language, including all language subdomains (21 items), is denoted LangScore in the subsequent sections. The memory domain consists of one subdomain only (11 items). Each FTF item is to be scored as: does not apply (0 points), applies sometimes/to some extent (1 point), or applies (2 points). A mean score (0–2 points) can be calculated for each domain and, if necessary, for each subdomain. Higher points indicate that parents experience more concern. The percentile classes used in the FTF are as follows: < 25% – less difficulties than average; 25–74% – average skills; 75–89% – minor difficulties; 90–97% – difficulties; > 98% – considerable difficulties.

The FTF norms for five-year-old children are based on a Finnish sample of 769 children (Korkman, et al., 2004b). Limits have been set to identify children with difficulties and belonging to the risk group (90%) or children with considerable difficulties (98%). The reliability of the FTF is very good (Airaksinen, Michelsson & Jokela, 2004; Kadesjö et al., 2004; Korkman et al., 2004b; Trillingsgaard et al., 2004). Also, the clinical validity of the FTF has been demonstrated (Bohlin & Janols, 2004; Trillingsgaard et al., 2004). In screening for developmental problems FTF has a high sensitivity (93%) but low specificity (63%) in identifying children with developmental disorders (Korkman, Jaakkola, Ahlroth, Pesonen & Turunen, 2004a).

5.2.2 Statistical analysis of LUKIVA and FTF data

Statistical analysis was performed using the IBM SPSS Statistics 24 program. Spearman correlation analysis was performed to determine the strength of the relationship between LUKIVA-test variables (RAN, letter knowledge, LUKIVA-index) and FTF language (comprehension, expression, communication, and LangScore) and memory variables.

Standard multiple regression analysis was performed to determine how much age 5;0 language skills (dependent variable), as measured using FTF, can be explained by LUKIVA-index. Two models were constructed. In model 1, LUKIVA-index at age 3;6 was used as a predictor (independent) variable. In model 2, LUKIVA-index at age 5;0 was used as a predictor (independent) variable together with FTF memory skills at age 5;0. Gender and maternal education were included in both models as predictor variables. Maternal education was categorized according to years of education as ≤ 12 years or > 12 years. As standardized residuals, i.e. the difference between predicted values and actual values, were close to linear and normally distributed, as determined using the Shapiro-Wilk normality test, the data was deemed suitable for multiple regression analysis. In addition, no outliers were found using a criterion of $p < .001$ for Mahalanobis distance, a test for identifying multivariate outliers. A p-value of $< .05$ was considered statistically significant in all statistical tests.

5.3 Ethical aspects

The protocol of the Norming study of the Finnish short form version of the MacArthur Scale of Communicative Development Inventories has been approved by the ethics committee of the University of Turku (12/2010). Permission for data collection at child health clinics in Turku was granted by the Turku Welfare Division (Turun terveystoimi 3/2011).

6 RESULTS

6.1 Descriptive statistics of LUKIVA and FTF data at ages 3;6 and 5;0

Descriptive statistics (median, mean, standard deviation, and range) for the LUKIVA-test measures at age 3;6 are presented in Table 1. Children aged 3;6 named the 30 items in the RAN subtest at an average rate of one minute. In addition, the children named on average four letters. The ranges for all variables were wide.

Table 1. Descriptive statistics for LUKIVA-test at age 3;6.

Test variables	Median	*M*	*SD*	Range
RAN (in seconds)	63	61.65	11.96	38–93
LK	0	4.43	7.06	0–21
LUKIVA-index	10	9.28	9.32	0–38

Abbreviations: RAN = rapid automatized naming, LK = letter knowledge, *M* = mean, *SD* = standard deviation.
Test data ranges: RAN: 20–180 seconds; LK: 0–23 letters; LUKIVA-index: 1–100.
N = 40 for LUKIVA-test variables.

In Table 2 descriptive statistics for LUKIVA-test measures and language and memory domains and language subdomains (comprehension, expression, communication) of FTF measures at age 5;0 are presented. At this age children were much faster at naming than at age 3;6, requiring on average 45 seconds to name 30 familiar items. The ranges for RAN and LUKIVA-index were smaller at age 5;0 compared to age 3;6. Five-year-old children could name on average close to 13 letters. Letter knowledge had a somewhat wider range at age 5;0 than at age 3;6. The FTF scores also exhibited wide ranges.

The LUKIVA-test data shows, that RAN and LUKIVA-index decreases and letter knowledge increases from age 3;6 to 5;0. The mean LUKIVA-index in both age groups were within 1–20, which corresponds to age-appropriate pre-reading skills (Puolakanaho et al., 2011). At age 3;6 three children (7.5%) and at age 5;0 two children (5%) had a LUKIVA-index > 20, corresponding to future risk for reading disability in school. The children that had a LUKIVA-index > 20 at age 3;6 were not the same as those children who had a LUKIVA-index > 20 at age 5;0.

Table 2. Descriptive statistics for LUKIVA-test and FTF language and memory domains and language subdomains at age 5;0.

Test and variables	Median	*M*	*SD*	Range
LUKIVA				
RAN (in seconds)	42	43.24	7.33	32–62
LK	15	12.78	8.16	0–23
LUKIVA-index	4	6.90	7.09	0–27
FTF				
Language				
Comprehension	0.20	0.21	0.24	0–0.80
Expression	0.15	0.19	0.19	0–0.77
Communication	0.00	0.21	0.28	0–1.00
LangScore	0.14	0.20	0.17	0–0.67
Memory	0.30	0.36	0.33	0–1.36

Abbreviations: RAN = rapid automatized naming, LK = letter knowledge, FTF = Five to Fifteen, *M* = mean, *SD* = standard deviation.
Test data ranges: RAN: 20–180 seconds; LK: 0–23 letters; LUKIVA-index: 1–100; FTF language and memory variables: 0–2.
N = 40 for LUKIVA-test variables, *N* = 37–40 for FTF variables.

At the group level, children in the present study had mean a LangScore, as measured using the FTF parental questionnaire, corresponding to the 25th–74th percentile. This corresponds to average skills. The standard deviations and ranges were, however, quite large. The group included children with skills varying from less difficulties than average (< 25th percentile) to children with difficulties (90th–97th percentile) within the language domain. Four children (10%) had minor difficulties (75th–89th percentile) and three children (7.5%) had difficulties (90th–97th percentile).

The mean group values for the FTF memory domain corresponded to the 75th–89th percentile, i.e. minor difficulties. This indicated, that the group included children with some memory problems. Children presented with more severe difficulties within the memory domain compared to the language domain. Eleven children (27.5%) had minor difficulties (75th–89th percentile) and nine children (22.5%) had difficulties (90th–97th percentile) within the memory domain. No child had considerable difficulties (> 98th percentile) in the language domain but in the memory domain two children (5%) had considerable difficulties.

The data set contained three children (7.5%) with familial risk for dyslexia. Thus, out of the total of 40 children, 37 children (92.5%) did not have a familial risk for dyslexia. Table 3 presents LUKIVA-test variables at ages 3;6 and 5;0 for the three children with familial risk for dyslexia. Descriptive statistics (median, mean, standard deviation) and percentiles for the FTF language and memory domains at age 5;0 for these children are also presented in Table 3.

Table 3. LUKIVA-test variables at ages 3;6 and 5;0 and FTF language and memory domain means, standard deviations and percentiles at age 5;0 for three children with familial risk for dyslexia.

	ID13		ID20		ID64	
	Age 3;6	Age 5;0	Age 3;6	Age 5;0	Age 3;6	Age 5;0
LUKIVA						
RAN (in seconds)	49	35	58	38	53	41
LK	0	19	19	20	0	9
LUKIVA-index	37	4	0	4	38	18
FTF						
LangScore						
Median	–	0	–	0	–	0
Mean ± SD*	–	0.14 ± 0.36	–	0.05 ± 0.22	–	0.57 ± 0.68
Percentile	–	25–74	–	25–74	–	90–97
Memory						
Median	–	0	–	0	–	1
Mean ± SD*	–	0.73 ± 0.90	–	0.33 ± 0.82	–	0.64 ± 0.50
Percentile	–	90–97	–	75–89	–	90–97

Abbreviations: RAN = rapid automatized naming, LK = letter knowledge, FTF = Five to Fifteen, *SD* = standard deviation.
Test data ranges: RAN: 20–180 seconds; LK: 0–23 letters; LUKIVA-index: 1–100.
FTF percentile classes: < 25% – less difficulties than average; 25–74% – average skills; 75–89% – minor difficulties; 90–97% – difficulties; > 98% – considerable difficulties.
*Means and standard deviations of FTF domains for individual children. LangScore includes 21 items, memory includes 11 items.

All three children with familial risk for dyslexia had faster RAN performance time at both ages than the group average. In letter naming the children performed according to group averages, except for the 19 letters named correctly by ID20 at age 3;6. At age 3;6 ID13 and ID64 presented with LUKIVA-index > 20, which corresponds to risk for future reading disability in school. At age 5;0 LUKIVA-index was < 20 for all children, corresponding to age-appropriate pre-reading skills.

Of the children with familial risk for dyslexia, ID64 presented with difficulties within the language domain (90^{th}–97^{th} percentile). ID13 and D64 had difficulties (90^{th}–97^{th} percentile) within the memory domain.

6.2 Association of pre-reading skills at age 3;6 and pre-reading and language and memory skills at age 5;0

Spearman's correlation coefficient values (r_s-values) for the associations between LUKIVA-test and FTF variables are presented in Table 4. LUKIVA-test variables at age 3;6 correlated positively and significantly with the corresponding variables at age 5;0. The association between ages was particularly strong for letter knowledge. Some of the LUKIVA-test variables, measured at age 3;6 and 5;0, were also significantly associated with age 5;0 language and memory skills, as measured using FTF. The significant but negative correlations between letter knowledge and several language measures reflects the fact, that proficiency in letter knowledge was associated with low language measures, i.e. less concern. At age 5;0, language and memory skills correlated positively and significantly.

Table 4. Spearman's correlation co-efficient values (r_S-values) between pre-reading skills at ages 3;6 and 5;0 and language and memory skills at age 5;0.

Variables	1	2	3	4	5	6	7	8	9	10	11
3;6-year-olds											
LUKIVA											
1. RAN	–										
2. LK	-.31	–									
3. LUKIVA-index	–	–	–								
5;0-year-olds											
LUKIVA											
4. RAN	.35*	-.01	–	–							
5. LK	-.39*	.80***	–	.06	–						
6. LUKIVA-index	–	–	.64**	–	–	–					
FTF											
Language											
7. Comprehension	.34*	-.37*	.54***	-.03	-.31	.27	–				
8. Expression	.39*	-.35*	.39*	.27	-.42**	.46**	.31*	–			
9. Communication	.17	.25	-.19	.15	.04	-.02	.10	.29	–		
10. LangScore	.39*	-.32*	.41**	.17	-.38*	.39*	–	–	–	–	
Memory											
11. Memory	.14	-.22	.34*	-.02	-.22	.23	.47**	.43**	.17	.50***	–

Abbreviations: RAN = rapid automatized naming, LK = letter knowledge, FTF = Five to Fifteen.

N = 40 for LUKIVA-test variables, *N* = 37–40 for FTF variables.

Statistically significant correlations are marked with an asterisk: *p < .05, **p < .01, ***p < .001.

6.3 Regression analysis of factors explaining age 5;0 language skills

Standard multiple regression analysis was performed to analyze how much of the language skills at age 5;0, as measured using FTF, could be explained by age 3;6 LUKIVA-index together with gender and maternal education as unique contributors. A significant regression equation was found (Table 5, Model 1). The adjusted R^2 value of .168 indicated that 16.8% of the variability in age 5;0 language skills, which is a considerable amount of the total variability, could be explained by age 3;6 LUKIVA-index, gender and maternal education.

A second standard multiple regression was performed with language skills at age 5;0 as the dependent variable and LUKIVA-index and memory skills at age 5;0, together with gender and maternal education, as independent variables. A significant regression equation was found (Table 5, Model 2). The adjusted R^2 value of .356 indicated that 35.6% of the variability in age 5;0 language skills could be explained by age 5;0 LUKIVA-index, age 5;0 memory, gender and maternal education. Memory skills added markedly and significantly to how much the predictor factors explained age 5;0 language skills.

Table 5. Results for the standard multiple regression analysis. In both models, the FTF LangScore measured at age 5;0 was used as a dependent variable. In model 1, LUKIVA-index at age 3;6 was used as a predictor variable together with gender and maternal education. In model 2, LUKIVA-index and FTF memory skills at age 5;0 were used as a predictor variables together with gender and maternal education.

Model	Variables	R^2	adjusted R^2	B	$\boldsymbol{\beta}$	sr_i^2
1		.232*	.168*			
	LUKIVA-index age 3;6			0.008**	0.455**	.454**
	Gender			0.030	0.091	.091
	Maternal education			0.005	0.011	.011
	Intercept			0.068		
2		.422**	.356***			
	LUKIVA-index age 5;0			0.007*	0.314*	.284*
	FTF Memory age 5;0			0.239**	0.472**	.426**
	Gender			-0.017	-0.050	-.048
	Maternal education			0.001	0.003	.002
	Intercept			0.086		

Abbreviations: FTF = Five to Fifteen, R^2 = coefficient of determination, B = unstandardized regression coefficient, $\boldsymbol{\beta}$ = standardized regression coefficient, sr_i^2 = semipartial correlation.
N = 40 for LUKIVA-test variables, N = 37–40 for FTF variables.
Statistically significant values are marked with an asterix $*p < .05$, $**p < .01$, $***p < .001$.

7 DISCUSSION

The aim of this thesis was to study the relationship between pre-reading and language and memory skills in preschool-aged children. Specifically, the association between early pre-reading skills at age 3;6 and pre-reading and language and memory skills at age 5;0 was studied. Whether early pre-reading skills at age 3;6 can explain language skills at age 5;0 was also a focus of this thesis. In addition, it was of interest to determine, whether memory skills add to the prediction of language skills by pre-reading skills at age 5;0.

The main findings of this study are as follows. Age 3;6 and 5;0 LUKIVA-test variables correlated significantly with each other and with age 5;0 language skills. LUKIVA-index at age 3;6 explained a considerable amount of age 5;0 language skills. In addition, LUKIVA-index and memory skills at age 5;0 explained a substantial amount of age 5;0 language skills. Memory skills added significantly to how much age 5;0 LUKIVA-index and memory explained the variability in age 5;0 language skills.

7.1 Association of age 3;6 and 5;0 LUKIVA variables

In this study, RAN at age 3;6 correlated positively and significantly with RAN at age 5;0. This is in line with the positive correlation of RAN at ages 3;6 and 5;6 reported by Puolakanaho and colleagues (2011). The positive association between RAN at ages 3;6 and 5;0 suggests that RAN is developmentally stable from age 3;6 to 5;0, thus extending previous results by Lepola and coworkers (2005) and Ozernoz-Palchik and coworkers (2017) showing that RAN is developmentally stable in 5–7-year-old children. That RAN is developmentally stable means that RAN performance time in early development is associated with RAN performance time later in development. Fast performance time in RAN has been linked to good concurrent language skills in five-year-old children (Adlof et al., 2010; Caravolas et al., 2012; Papadimitriou & Vlachos, 2014). Slow RAN has, in turn, been associated with developmental language disorder (Aguilar-Mediavilla, Buil-Legaz, Pérez-Castelló, Rigo-Carratalá & Adrover-Roig, 2014; Vandewalle, Boets, Chesquière & Zink, 2010; Waber, Wolff, Forbes & Weiler, 2000). Rapid automatized naming in 3;6-year-old preschool children may thus be an indicator of language skills during later childhood.

Generally RAN performance time decreased from age 3;6 to age 5;0. This is in line with previously reported data showing that RAN performance time decreases with age (e.g. Adlof et al., 2010; Compton, 2003; Furnes & Samuelsson, 2011; Georgiou et al., 2006; Puolakanaho et al., 2008). Rapid automatized naming performance times of the children in this study concur with the data and data estimates of Finnish-speaking children at ages 3;6 and 5;0 performing the same RAN task (Puolakanaho et al., 2011).

Letter knowledge has also been shown to be developmentally stable in 5–7-year-old children (Adlof et al., 2010; Lonigan et al., 2000; Ozernoz-Palchik et al., 2017). Results from this study, where letter knowledge at age 3;6 correlated positively and strongly with letter knowledge at age 5;0, supports previously reported results by Puolakanaho and colleagues (2011). It thus appears that letter knowledge, like RAN, is developmentally stable from age 3;6 to age 5;0. Letter knowledge in five-year-old children has previously been shown to correlate positively with concurrent language skills (Adlof et al., 2010; Caravolas et al., 2012). In children with developmental language disorder letter learning is frequently delayed (Cordewener, Bosman & Verhoeven, 2012). Letter knowledge, being developmentally stable in preschool children from as early as age 3;6, may thus partly reflect future language development.

On average, the children in the current study named more letters correctly than the children in the studies by Puolakanaho and colleagues (2011) and Torppa end colleagues (2006). The lower amount of correctly named letters in the study by Torppa end colleagues (2006) might be explained by the higher presence of children at risk for dyslexia in their sample compared to the current sample (51.6% vs. 7.5%). That preschool-aged children at risk for dyslexia have previously been shown to correctly name fewer letters than children without risk for dyslexia supports this explanation (Gallagher, Frith & Snowling, 2000). At age 3;6 the children in the current study also correctly named more letters than children of the same age with and without familial risk for dyslexia in the study by Puolakanaho and colleagues

(2011). This might be a consequence of difference in sample size, resulting in more accurate numbers in the study by Puolakanaho and coworkers (2011), which included a much larger sample size. Furthermore, the time of data acquisition may have affected children's knowledge of letters. Finnish education policies have changed over the years as well as societal attitudes concerning letter learning and learning to read. The data from the Jyväskylä Longitudinal Study of Dyslexia, on which the reports by Puolakanaho and colleagues are based, comes from children of parents who were expecting a baby during 1993–1996 (The Jyväskylä Longitudinal Study of Dyslexia, n.d.). The data from 3;6- and 5;6-year-old children has been collected around year 2000. The data of the current study was collected between 2011–2017, with data from 3;6- and 5;0-year old children having been collected during the latter part of this interval. Children in the current study were thus born around 15 years later than the children in the Jyväskylä Longitudinal Study of Dyslexia. The children in this study, who were born later, may thus have been taught letters earlier than what was customary in previous years. In comparison to Finnish-speaking children, 2–5-year-old English-speaking children named more letters correctly (Phillips et al., 2012). It appears, that English-speaking children learn to name letters earlier than Finnish-speaking children. Formal teaching of letters might be started earlier in English-speaking countries due to the fact that English has a highly irregular and thus more complicated orthography than does Finnish (Aro & Wimmer, 2003).

The LUKIVA-index is based on RAN, letter knowledge, and familial risk for dyslexia. The association between LUKIVA-index at age 3;6 and the corresponding variable at age 5;0 was positive and significant and the correlation was strong. This means that there is a substantial relationship between LUKIVA-index at ages 3;6 and 5;0, with the level of performance at age 3;6 being associated with the same level of performance at age 5;0 and vice versa. This was expected as RAN and letter knowledge at age 3;6 correlated positively and significantly with RAN and letter knowledge at age 5;0 and the sample included the same children with and without familial risk for dyslexia at both ages. These results show, that LUKIVA-index is developmentally stable from age 3;6 to 5;0. This supports the use of LUKIVA-index in early assessment of pre-reading skills and in screening for children at risk for future reading disability. Rapid automatized naming, letter knowledge, and familial risk for dyslexia, i.e. the composite factors of the LUKIVA-index, have been linked to concurrent language skills in five-year-old children (Adlof et al., 2010; Caravolas et al., 2012; Papadimitriou & Vlachos, 2014; Torppa et al., 2010). LUKIVA-index at age 3;6 may thus be related to language skills later in development in addition to being related to literacy skills.

7.2 Association of age 3;6 and 5;0 LUKIVA variables and age 5;0 language and memory skills

In this study, five-year-old children as a group had age-appropriate language skills, as measured using FTF. This is line with results presented by Rautava and colleagues (2010), who studied development and behavior of five-year-old very low birthweight infants in comparison to full-term controls. The results of the present study are also in line with the FTF language norms (Korkman et al., 2004b).

Age 5;0 language skills, i.e. LangScore, correlated significantly with RAN at age 3;6 and letter knowledge at ages 3;6 and 5;0, but not with RAN at age 5;0. Age 5;0 language skills also correlated positively and significantly with age 3;6 and 5;0 LUKIVA-index. The correlation between age 5;0 language skills and age 3;6 RAN was positive as lower language measures, i.e. less concern, was associated with faster RAN performance time. The negative correlation between age 5;0 language skills and letter knowledge at ages 3;6 and 5;0 reflected the association between low language measures and proficiency in letter knowledge. Previous studies have shown, that receptive and expressive language skills in five-year-old children are associated with concurrent RAN performance time and letter knowledge (Adlof et al., 2010; Caravolas et al., 2012; Lonigan et al., 2000; Ozernoz-Palchik et al., 2017; Papadimitriou & Vlachos, 2014). That age 5;0 RAN was not significantly associated with age 5;0 language skills in the current study was unexpected due to previous results by several research groups linking these skills. This might, however, be explained by the use of different language tests to measure language skills in other studies. In this study, a parental questionnaire, FTF, was used to measure language skills. Other studies have mainly used child administered tests to measure language skills. Results from the FTF may not be directly comparable with results from child administered tests. Consequently, the association between RAN and language skills may vary depending on the language test used. The relationship between RAN and/or letter knowledge at age 3;6 and language skills at age 5;0 has not, to my knowledge, been studied before. This study shows, that RAN, letter knowledge and LUKIVA-index at age 3;6 are significantly associated with receptive and expressive language skills at age 5;0. Weak pre-reading skills and a high LUKIVA-index at age 3;6 may therefore be associated with weak future language skills. The results presented here add important information to our understanding of language development.

As a group the children in the present study had minor difficulties within the memory domain, as measured using FTF. This means that some of the children had weaker memory skills than children of this age on average. This deviates from the results reported in the study by Rautava and coworkers (2010), where children had on average age-appropriate memory skills. The results presented in the current study are, however, very close to the mean score of the FTF memory norms at age five (Korkman et al., 2004b). The FTF data in this study was collected at or within two weeks of the child's fifth birthday. The FTF norms were collected from children age 5;0–5;6, thus representing younger five-year-old children. Rautava and coworkers (2010) did not specify the mean age or age range of five-year-old control children in their study. It may be, that their sample included older five-year-old children, which could explain why the children in their study had a lower mean memory score. Older children generally have lower FTF memory scores than do younger children (Kadesjö et al., 2004; Korkman et al., 2004b).

Memory skills at age 5;0 correlated positively and significantly with LUKIVA-index at age 3;6, but not with LUKIVA-index at age 5;0. Papadimitriou and Vlachos (2014) and Caravolas and coworkers (2012) have previously shown, that faster RAN performance time is associated with better verbal short-term memory in five-year-old children. Caravolas and colleagues (2012) also found, that proficiency in letter knowledge at age five correlates with good verbal short-term memory. In the current study, memory skills were evaluated using the FTF parental questionnaire. The items in the FTF memory domain covers questions on short-term memory, working memory and long-term memory. Results obtained using the

FTF memory domain, including those of the present study, can therefore not be directly compared with tests measuring only short-term memory, working memory or long-term memory. Importantly, LUKIVA-index at age 3;6 correlated significantly with age 5;0 memory skills in this study. A high LUKIVA-index at age 3;6 may thus be associated with weak memory skills.

In this study, memory skills at age 5;0 were significantly associated with concurrent language skills. Language learning is known to be heavily dependent on memory and receptive, expressive and narrative language have been linked to verbal short-term memory, verbal working memory and long-term memory (Gathercole & Baddeley, 1989; Gillam et al., 2009; Fivush, 2011; Florit et al., 2009; Lepola et al., 2012; Nelson, 1993; Peterson, 2002; Potocki et al., 2013; Verhagen & Leseman, 2016). The results from this study show, that memory correlates positively with receptive and expressive language skills, thus supporting earlier research findings. As language learning is strongly dependent on memory, language development will be negatively affected by weak memory skills. It is therefore important to evaluate memory skills in addition to language skills in children who are facing difficulties in their language development.

Of the children participating in this study, three children (7.5%) had familial risk for dyslexia. This corresponds quite well to the prevalence of familial risk for dyslexia in Finland, which is ca 6% (Puolakanaho et al., 2011). The slightly higher percentage in this study might be a consequence of the small sample size. The children with familial risk for dyslexia who participated in the present study had pre-reading, language and memory skills close to those of the group. At-risk children even had faster RAN performance times than the group on average. A genetic disposition for dyslexia does not necessarily mean that the child will have problems in language development or in learning to read or that he or she will face such difficulties in the future. Pre-reading, language and memory skills of children with familial risk for dyslexia should, however, be studied in detail as these children have increased risk for linguistic difficulties (Bishop & Snowling, 2004; Lyytinen et al., 2004; McArthur et al., 2000; Torppa et al., 2010).

7.3 The role of pre-reading and memory skills in language development at age 5;0

Results from multiple regression analysis showed, that age 3;6 LUKIVA-index explained close to 17% of the variability in age 5;0 language skills when gender and maternal education were taken into consideration. Gender and socioeconomic status, measured mainly by the level of maternal education, have previously been linked to language development (Bleses & Vach, 2013; Taylor, Zubrick & Rice, 2013). Of these predictor variables, age 3;6 LUKIVA-index was by far the largest and the only statistically significant unique predictor of age 5;0 language skills. Gender and maternal education did not contribute significantly to the prediction of age 5;0 language skills. This may be due to the fact, that even though these factors have been linked to language development they have been shown to share very little of the variance (Rescorla & Dale, 2013). It thus seems, that in preschool-aged children pre-reading skills, together with familial risk for dyslexia, are stronger predictors of language development than are gender and socioeconomic status.

To my knowledge, this is the first study examining whether pre-reading skills of children with or without familial risk for dyslexia can explain future language skills. Previous studies concerning the predictive power of pre-reading skills have mainly focused on predicting future reading skill (e.g. Adlof et al., 2010; Furnes & Samuelsson, 2011; Leppänen, Niemi, Aunola & Nurmi, 2008; Lonigan et al., 2000; Papadimitriou & Vlachos, 2014; Puolakanaho et al., 2008; Torppa et al., 2010). This longitudinal study, adding valuable information to the way it is possible to explain future language skills, is thus unique in its kind. The results presented here confirm, that the LUKIVA-test provides important information regarding language development already at age 3;6.

Results from the second multiple regression model showed, that language skills at age 5;0 were explained considerably by LUKIVA-index at age 5;0, memory skills at age 5;0, gender and maternal education. Together, these factors explained ca 36% of the variability in age 5;0 language skills. Of these factors, age 5;0 LUKIVA-index and age 5;0 memory explained a substantial and significant amount of age 5;0 language skills, with memory being the largest unique predictor. Of the independent variables in the regression analysis, memory contributed 43% of the total unadjusted variance and LUKIVA-index contributed 28%. Memory is essential for language development. Previous studies have, however, mainly focused on the study of verbal short-term memory, verbal working memory or long-term memory in isolation in relation to language development. Verhagen and Leseman (2016) showed, for example, that receptive vocabulary and morphological and syntactical skills in five-year-old Dutch-speaking children are predicted by verbal short-time memory measured at the same age. The authors also concluded, that acquisition of grammar was predicted by verbal working memory. As the memory domain in the FTF covers questions on different parts of memory, as mentioned above, the results presented in this study cannot be directly compared with tests measuring verbal short-term memory, verbal working memory or long-term memory. The results of this study do, however, support previous research in showing that memory skills explain concurrent language skills. This is, as far as I know, the first study combining pre-reading skills and memory in prediction of concurrent language skills. The results of the present study showed, that concurrent memory skills markedly and significantly added to how much pre-reading skills, memory, gender and maternal education explain language skills in five-year-old children.

7.4 Strengths and limitations of the study

The greatest strength of this study is its longitudinal nature. This made it possible to study whether data from two different time points are associated. The longitudinal nature of the study also made it possible to determine, using multiple regression, whether pre-reading skills at age 3;6 can explain language skills at age 5;0 to any considerable amount. Another advantage of the current study is sample size, which is acceptable, thus allowing statistical analysis to be performed. A larger sample size would, however, yield more reliable results with smaller risk for errors. An additional advantage of the sample is that it included a comparable number of boys and girls. This allowed gender to be used as a predictive variable in the regression analysis. Socioeconomic status could also be included as a predictive factor in the regression analysis as information regarding mothers' education was available.

The sample did not include enough children with LUKIVA-index > 20 to allow group comparison of children at risk for future problems in learning to read and children without risk. The small number of children with familial risk for dyslexia did also not allow statistical analysis between groups of children with or without risk for dyslexia to be performed. The small number of at-risk children did, however, closely reflect the prevalence of at-risk children in the general population. As such, all children were included in the correlation and multiple regression analysis, thus representing the general population quite well, at least in the sense of prevalence for dyslexia.

7.5 Methodology

The LUKIVA-test is a reliable method for assessing early pre-reading skills in 3;6–5;6-year-old children and for identifying children at risk for future reading disability (Puolakanaho et al., 2011). The test is based on three key factors: RAN, letter knowledge, and familial risk for dyslexia. It takes approximately five minutes to complete the LUKIVA-test. One of the main results presented in this thesis shows, that the LUKIVA-test administered at age 3;6 can give important information regarding language development. The LUKIVA-test explained close to 17%, a substantial amount, of the variability in age 5;0 language skills. This suggests, that the LUKIVA-test may be used at age 3;6 in screening for children who will present with weak language skills at age 5;0. The LUKIVA-test can be administered quickly, thus not requiring a lot of time from the examiner or from the child. Especially when used for screening purposes, where lots of children are examined, the time required to administer the test is of essence.

The FTF parental questionnaire is a sensitive, reliable and valid method for evaluating development and behavior of 5–15-year-old children and adolescents (Korkman et al., 2004b). In this study, the language and memory domains of the questionnaire were utilized, including a total of 32 items to be answered by the parents. Taking only these parts of the questionnaire into consideration the questionnaire can be completed relatively fast. Completion of the whole questionnaire will require some additional time. The FTF is suitable as a screening tool as parents can be asked to fill out the questionnaire at home in their own time. As the FTF is filled out by parents or guardians the subjective opinion of the parent may influence the answers, affecting the accuracy of the test.

7.6 Clinical implications

The results of the present study add to and extends previous knowledge regarding early childhood development of pre-reading and language skills. This has clinical significance as increased knowledge allows for more sensitive and specific screening methods for early identification of children at risk for language impairment to be developed. Early recognition of children at risk for language impairment allows for support measures to be inserted and intervention to be started at even younger ages. This, in turn, may reduce language impairment and prevent accumulation of problems.

7.7 Future perspectives

It would be intriguing to repeat the study with a sample including enough children with LUKIVA-index > 20 at age 3;6 to determine whether a group difference can be seen in age 5;0 language and memory skills, as measured using FTF. This kind of setup would allow one to conclude whether weak pre-reading skills and LUKIVA-index > 20 at age 3;6 correlates with and explains weak language skills at age 5;0. It would also be interesting to repeat the study with more children with familial risk for dyslexia. That would allow group comparisons to be made between children with or without familial risk for dyslexia. This would clarify whether presence or absence of familial risk for dyslexia results in group differences in FTF language and memory scores.

Speech and language pathologists traditionally measure language skills in five-year old children by using standardized tests, for example Reynell Developmental Scales (RDLS) III, Boston Naming Test or Token test. Reynell Developmental Scales III is a reliable test of receptive and expressive language skills in 2–7-year-old children (Kortesmaa, Heimonen, Merikoski, Warma & Varpela, 2001). As the RDLS III measures both receptive and expressive language skills it would be of value to analyze the relationship between the FTF measures of the language domain and subdomains (receptive and expressive language) from this study with RDLS III measures from the same children at the same age, to see whether these measures are significantly associated. Some of the FTF domains, including language and memory, have been shown to be significantly associated with the corresponding domains of NEPSY, a neuropsychological assessment tool used by psychologists (Korkman et al., 2004a). This supports the clinical validity of these domains of the FTF in screening for developmental disorders. Language subdomains of the FTF have, to my knowledge, not been correlated with any other standardized test. Studying the association of FTF language domain and subdomains with standardized language tests would give more information on how reliable this parental questionnaire is in evaluating receptive and expressive language in five-year-old children.

This study shows, that age 3;6 pre-reading skills and LUKIVA-index are associated with and explains a considerable amount of age 5;0 language skills, as measured using FTF. These screening methods may thus aid in identification of children with weak language skills who may be in need of additional measures to support their language development. The important question is therefore whether the group results presented in this thesis apply to individual children or whether additional screening methods are needed to identify those individual children who will face problems in the future. This, and the above-mentioned issues, remains to be resolved by future research.

8 CONCLUSIONS

In this longitudinal study, pre-reading skills and LUKIVA-index at ages 3;6 and 5;0 and language and memory skills at age 5;0 were studied. It was concluded, that pre-reading skills and LUKIVA-index at ages 3;6 and 5;0 correlated positively and significantly with each other. These results extend previous research in showing, that pre-reading skills are developmentally stable in 3;6–5;0-year-old children. A novel finding of the present study was, that LUKIVA-index at age 3;6 explains a considerable amount of language skills at age 5;0, as measured using FTF. In addition, it was shown, that memory skills at age 5;0 significantly and markedly adds to the explanation of age 5;0 language skills by age 5;0 LUKIVA-index. Pre-reading skills in 3;6-year-old children may thus give important information regarding future language development. These factors may possibly be used to identify children with weak language skills, who are in need of additional support in their language development.

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