The Role of Working Memory in the Development of Morphological Awareness

Pre-school Working Memory as a Longitudinal Predictor of Morphological Awareness in Early School Years

Kristin Simonsen

Master Thesis in Special Needs Education

Institute of Special Needs Education

Faculty of Educational Sciences

UNIVERSITY OF OSLO

30th of June 2020

The Role of Working Memory in the Development of Morphological Awareness

Pre-school Working Memory as a Longitudinal Predictor of Morphological Awareness in Early School Years

© Kristin Simonsen

2020

The Role of Working Memory in the Development of Morphological Awareness: Pre-school Working Memory as a Longitudinal Predictor of Morphological Awareness in Early School Years

Kristin Simonsen

http://www.duo.uio.no

Abstract

Background and Rationale

Despite a substantial consensus in the literature of the important role of pre-school working memory in supporting language abilities during pre-school and early school years, knowledge of the associations between working memory and morphological awareness at this age seems absent. Morphological awareness is a metalinguistic ability that enables the efficient analysis and decomposition of morphologically complex words, and has been widely recognised for being essential to children's vocabulary building and literacy achievements during early school years. The rationale of the present study is to contribute knowledge of the cognitive mechanisms that allow for morphological awareness to facilitate these achievements. Based on this rationale, the research question informing the present study is:

> Does working memory predict the development of morphological awareness over time?

Method

This longitudinal study investigates the prediction of pre-school working memory upon morphological awareness amongst Norwegian speaking children, and is written in association with the research project *NumLit* from the Institute of Special Needs Education at the University of Oslo. Data were obtained from 216 of the participant children in the NumLit-project. The children were all born in 2012, and have been tested in their final year of Pre-school, Grade 1, and Grade 2. Data from tasks measuring working memory, nonverbal-IQ, and receptive vocabulary were obtained from pre-school, while data from tasks measuring morphological awareness (meta-inflectional and meta-derivational awareness) were obtained all years.

Analyses

The data were analysed by bivariate correlations. Additionally, two hierarchical multiple regression analyses were employed with morphological awareness in Grade 1 and Grade 2 as respective outcome measures, and a statistical control of the autoregressor, receptive vocabulary, and nonverbal-IQ. All analyses were run by IBM SPSS Statistics for Macintosh,

version 26.0 (IBM, 2019), with the exception of Revelle's Omega, which was estimated in Jamovi, version 1.2 (The Jamovi Project, 2020).

Results and Conclusion

The bivariate correlations revealed that working memory significantly correlated with morphological awareness in Grade 1 and Grade 2 (all $p < .001$). In hierarchical regression analyses, the working memory measures failed to account for any variance in morphological awareness from Grade 1 ($\Delta R^2 = .007$, $p = .348$). In morphological awareness from Grade 2, a unique significant contribution of approximately 4% ($\Delta R^2 = .039$, $p = .004$) was attributable to working memory, above and beyond the effects of prior morphological awareness, receptive vocabulary, and nonverbal-IQ. The results show that although working memory in pre-school fails to predict morphological awareness in the first grade, working memory is a unique contributor to individual achievements in morphological awareness in the second grade. It is argued that such a result is indicative of a strengthening involvement of working memory as children develop higher meta-levels of morphological awareness. It is moreover postulated that the shift in working memory's prediction upon morphological awareness partly derives from the fact that the constructs converge in the second grade as a result of their shared contribution to reading comprehension. The results emphasise the importance of providing efficient pathways to language and reading comprehension via morphological analysis to those children with a limited working memory span, making the finding of this study highly relevant for speech and language therapists, and special needs educators in general. Further research is necessary in order to investigate whether the results obtained in the present study are consistent, and if the longitudinal prediction of working memory upon morphological awareness proves differently across higher grade-levels, and/or across languages.

Preface

I have thoroughly enjoyed the process of writing this thesis, and there are many to thank.

Firstly, to the researchers of the *NumLit* project, I am very thankful that you so willingly shared your data with me and welcomed me to the project as a research assistant. Without this, I would have been unable to immerse myself in such an interesting topic.

To Vasiliki Diamanti, I feel privileged to have had you as my supervisor. Thank you for being so generous with your encouragement, dedication, and knowledge. To my second supervisor Athanassios Protopapas, thank you for always taking the time to share of your knowledge and advice. I am grateful to have learned so much from you both.

I also need to thank all of my wonderful study friends, and my "to agentar" Anne-June and Pernille in particular. Thank you for making me cry from laughter every single time we are together. I am so glad I met you.

Birthe, thank you for being the best friend and flatmate I could have possibly had throughout my years of studying in Oslo. Stina, thank you for being you.

To my family, matters related to special needs education have always been a topic of discussion around the dinner table and I am very fortunate for this to have shaped my view of the world. To my mother and father, thank you for allowing me to occupy the house during intense periods of writing, and for cheering me on and making me laugh along the way. Halldor, thank you for being an intensely protective and supportive older brother. Kari, thank you for being a caring older sister and friend, and for always showing an interest in what I am doing.

June 2020,
Kristin Simonsen

Table of Contents

List of Figures

List of Tables

Word count: 22.997

1. Introduction

1.1 Background and Rationale

The ability to effectively comprehend and acquire new words is an essential skill in language development. Children who encounter unfamiliar words in oral and written contexts rely on their awareness of language to provide efficient routes to the pronunciation, spelling, and meaning of words (Carlisle, 2003; Kirby et al., 2012). A substantive amount of research has been dedicated to how an awareness of the smallest meaning-bearing units within words, denoted as morphemes, contributes to language learning (Gonnerman, 2018). Specifically, research has been consistent in its recognition of the importance of morphological awareness to early language and reading development, and has established morphological awareness to uniquely contribute to individual differences in vocabulary knowledge (McBride–Chang, Wagner, Muse, Chow, & Shu, 2005; Spencer et al., 2015), and reading and spelling abilities during early school years (Berninger, Abbott, Nagy, & Carlisle, 2010; Carlisle, 1995; Deacon & Kirby, 2004; Diamanti et al., 2017; Duncan, 2018; Manolitsis, Georgiou, Inoue, & Parrila, 2019; Nagy & Scott, 2000). Morphological awareness can be defined as the knowledge of how to apply rules of word formation on linguistic structures in order to understand and generate novel words (Carlisle, 1995; Kuo & Anderson, 2006). Furthermore, morphological awareness is metalinguistic ability, and therefore also refers to the capacity to reflect upon and manipulate morphemes at a conscious level (Kuo & Anderson, 2006). In detail, morphemes are systematically combined in word formation processes to form morphologically complex words comprising stems and affixes; the suffix *–ed* is, for example, systematically added finally to verb stems in English in order to indicate past tense (e.g. laugh*ed*, work*ed*) (Kirby et al., 2012). The awareness children have of the rule bound employment of morphemes permits them to utilise this knowledge to analyse the meaning of complex words by constituent morphemes, in turn allowing for the recombination of such word parts to create a meaningful whole (Kuo & Anderson, 2006; Zhang, Lin, Wei, & Anderson, 2014). Thus, children who are morphologically aware appreciate the semantic roles that different word forms play, making morphological awareness fundamental to overall language and reading comprehension (Carlisle, 2000). However, despite the acknowledged importance of morphological awareness in language and literacy acquisition, there seems to be a lack of knowledge of the cognitive mechanisms contributing to the development of this ability across early school years.

On the other hand, the capacity of the working memory has been found essential for complex tasks involved in early language development, such as learning, comprehension, and reasoning (Baddeley, 2000). In line with this, a considerable amount of research has identified working memory capacity to be a unique predictor of early language and reading abilities, such as language comprehension (Fitzpatrick & Pagani, 2012; Kidd, 2013; J. L. McDonald, 2008; Newbury, Klee, Stokes, & Moran, 2016), reading comprehension (Daneman & Merikle, 1996; Gathercole, Brown, & Pickering, 2003; McVay & Kane, 2012; Peng et al., 2018), reading speed (Johann, Könen, & Karbach, 2019), as well as overall early academic skills (Gathercole et al., 2003; Montoya et al., 2019). Working memory is referred to as a brain system with a limited and temporary storage capacity, where information is concurrently held and manipulated (Archibald & Gathercole, 2006; Baddeley, 2003, 2010, 2012; Baddeley & Hitch, 1974). It is a commonly held perception that working memory is a complex system that drives several subprocesses (Baddeley, 2000; Baddeley & Hitch, 1974), however, the nature and extent of the role of these working memory components to language processing remains a key theoretical issue.

In sum, both working memory and morphological awareness are critical factors in children's language and literacy development. Morphological awareness is a cognitive undertaking, and limitations in either linguistic or cognitive abilities are likely to affect its development (Carlisle, 2003). Provided the fact that early working memory capacity seems to be an excellent predictor to a range of linguistic skills, it may be hypothesised that this cognitive mechanism also is a contributor to individual morphological awareness achievements. Accordingly, the rationale of the present study is to provide insight of the role that pre-school working memory has in the development of morphological awareness during early school years. Whereas some research has investigated the associations between working memory and more implicit morphological knowledge (Daneman & Case, 1981; J. L. McDonald, 2008; Verhagen & Leseman, 2016), an understanding of the relationship between working memory and morphological awareness at the metalinguistic level seems absent. In particular, there is no longitudinal research to have examined such an association. Knowledge of the relationship between working memory and morphological awareness in young children is considered valuable; early language abilities have considerable implications for later academic attainment, psychosocial well-being, as well as the inclusion in higher education and later work life (Evans, Gillam, & Montgomery, 2018). To be aware of the underlying cognitive mechanisms that facilitate morphological awareness can help identify early precursors to later language abilities and contribute to an improvement of the way language and reading delays are treated, making this knowledge highly relevant for clinicians, such as speech and language therapists, as well as other special needs educators.

This thesis is written in association with the research project *"NumLit – Development of Numeracy and Literacy in Children"* from The Department of Special Needs Education at The University of Oslo. *NumLit* is an ongoing longitudinal research that, in short, studies the development of, and interrelations between, number, language, and literacy skills in approximately 250 children from the age of 5 until the age of 18. The project is now entering its third year, providing this thesis with data obtained from three waves of measurement.

1.1.1 Research Question

The aforementioned background and rationale has led to following research question:

> *Does working memory predict the development of morphological awareness over time?*

1.2 Delimitations

Limitations in morphological awareness and working memory capacity are both hallmarks of developmental language disorder (Bishop et al., 2017; Ullman, Earle, Walenski, & Janacsek, 2020), and possibly other developmental disorders. The present study provides results from data obtained from typically developing children, and the discussion will therefore centre on this group. However, the implications of the results in this study might inform the understanding of the relationship between working memory and morphological awareness also in children who do not follow a typical language development.

1.3 Structure of the Thesis

The first chapter of the thesis has outlined the background and rationale of the present study, leading to the research question.

In Chapter 2, the theoretical and empirical background for morphological awareness will be presented. The chapter will start by a description of the nature of morphology. The chapter thereafter moves on to describe the development of morphological awareness, and to discuss the role of morphological awareness as a metalinguistic ability, as well as its importance to vocabulary and literacy acquisition.

Chapter 3 presents the theoretical and empirical background for working memory, and describes the theoretical framework informing the understanding of working memory in the present study, which is the multi-component model by Baddeley and Hitch (1974) and Baddeley (2000). Subsequently, the role of working memory to language processing will be described, as well as the importance of working memory to later language and reading abilities.

Chapter 4 outlines existing research on the relationship between morphology and working memory, and summarises the theory, as well as the goals of the present study, in the rationale.

Chapter 5 engages with the methodological approach that has been taken in this study, and explains the data collection, and the statistical analyses that have been performed. Thereafter, the measurement tools of the variables will be described in detail. Finally, the chapter moves on to discuss issues pertaining to validity and reliability, as well as the ethical considerations that have been made.

In Chapter 6, the results of the statistical analyses will be presented.

Chapter 7 discusses the obtained results in light of the empirical and theoretical background presented earlier. Implications of the present study are also highlighted. The chapter then reflects on the findings in light of validity and reliability.

Chapter 8 arrives at the conclusion, and proposes possible limitations and future directions of the current study.

2. Theoretical and Empirical Background: Morphological Awareness

2.1 The Nature of Morphology

Languages are expressed by sounds that in turn are combined to convey meaning. The units of sounds within words can be denoted as phonemes, while meaning can be referred to as semantics. Letters or characters in written language, known as graphemes, are tied to phonology and concern the orthography of a language (Kirby & Bowers, 2018). Languages differ in their phoneme-grapheme transparency; in some languages, such as Finnish, phonemes may consistently correspond to one grapheme, whereas in other languages graphemes carry a variation of associated sounds (Seymour, Aro, & Erskine, 2003). Norwegian is a language that is considered to be semi-transparent, while English, on the other hand, has a more complex and opaque orthography (Seymour et al., 2003). The inconsistency of how words are written to how they are pronounced complicates reading and spelling acquisition, and demands that children have an awareness of phoneme-grapheme-relations (Carlisle & Nomanbhoy, 1993). Extensive research has thus established that *phonological awareness*, defined as the ability to consciously analyse and manipulate phonemes, is a prerequisite to reading development, particularly in the early stages that involve word decoding (Melby-Lervåg, Lyster, & Hulme, 2012). However, a case in research has been made that while phonological awareness is essential for reading abilities, it is not sufficient (Berninger et al., 2010; Carlisle, 2003; Duncan, 2018). Words in English and Norwegian, as well as in other languages of European origin, are constructed through the combination of phonological and morphological rules, deeming the language structure morphophonemic (Carlisle, 2003; Carlisle & Stone, 2005; Cunningham & Carroll, 2015; Lyster, Lervåg, & Hulme, 2016). It has consequently been established that morphology, as well as phonology, governs the pronunciation and spelling of words, and that *morphological awareness* is uniquely predictive of individual language and reading abilities (Carlisle, 1995, 2000; Carlisle & Nomanbhoy, 1993; Deacon & Kirby, 2004; Duncan, 2018; Mahony et al., 2000; Nagy & Scott, 2000).

Morphology is considered a binding agent that connects phonology, semantics and orthography (Kirby & Bowers, 2018; Kuo & Anderson, 2006). The linguistic domain of morphology can accordingly be described as the study of word structure, and more specifically the study of how morphemes convey meaning in oral and written contexts (Gonnerman, 2018). Correspondingly, a morpheme is the smallest unit within a word that carries semantic information (Carlisle, 2003; Kuo & Anderson, 2006). These meaning bearing units systematically provide grammatical information such as word class, verb tense, and quantity (Gonnerman, 2018). Distinctions can be made about various morpheme types; a morpheme is either free standing, such as the words *lamp* or *dog*, or it is bound to other morphemes and cannot convey meaning on its own, for instance *un-* in *unreal*, and *-ed* in *married* (Carlisle, 2007). Furthermore, morphemes take form as stems or affixes. A stem morpheme is the base of the word, and can be built upon to create other word forms, while affixes relate to units that are added to the stem. In the morphology of languages such as English and Norwegian affixes commonly concern two types: prefixes, which are units attached before the stem, and suffixes, which are units attached after the stem (Gonnerman, 2018).

Moreover, morphology regards word formation, in which morphemes function as building blocks that are combined to create meaning in word formation processes (Kuo & Anderson, 2006). Morphological analysis has therefore been proven important in giving access to the spelling and meaning of words, particularly in words where phoneme-grapheme relations are inconsistent (Nagy & Scott, 2000). The irregular relationship between spelling and sound relies on the regularity between spelling and meaning, in which the systematic employment of morphemes provides consistent patterns (Nagy & Scott, 2000). This can be identified when contrasting the consistent spelling of the suffix *-ed* to mark past tense in regular verbs, to its variation in pronunciation; for instance, the systematic spelling of the differently pronounced words *loaded, helped* and *poured* requires knowledge of the meaningful contribution each morphemic element brings (i.e. stem + suffix to indicate past tense) (Maynard, Brissaud, & Armand, 2018; Nagy & Scott, 2000). Relatedly, morphological analysis can facilitate pronunciation when encountering unfamiliar words in textual contexts. For example, the recognition of the prefix *re-* in the word *react* signals that the word should be pronounced differently to the similarly spelled stem morpheme *read* (Bowers, Kirby, & Deacon, 2010; Deacon & Kirby, 2004).

Pertinent to issues raised of grapheme-phoneme relations, word structures can be identified as more or less transparent at the morphemic level, which in turn influences how readily the structure of a word is recognised and comprehended. In word formation processes stem morphemes can undergo phonological shifts as well as orthographic shifts (Carlisle &

Stone, 2005). Phonological transparency is retained when the pronunciation of the stem is intact in derived words, as in *help-helpful*, as opposed to the phonological shift found in *sign-signature* (Carlisle & Stone, 2005). Likewise, the orthographic transparency of a word can be considered by the extent to which the spelling of the stem has been preserved in morphologically complex words (Carlisle & Stone, 2005).

Studies conducted on how children develop morphological awareness have mainly engaged with the acquisition of three types of morphology: inflections, derivations, and compounds. These domains will therefore be briefly presented below, before the following section moves on to discuss morphological awareness.

2.1.2 Domains of Morphology

Inflectional morphology refers to the process of attaching morphemes to a stem morpheme to alter its form, through the change of tense, gender, aspect, or other grammatical dimensions (Gonnerman, 2018; Maynard et al., 2018). In inflectional processes the semantic content of the word is preserved, while the alteration of the word is bound by syntactic demands (Gonnerman, 2018). These alterations are marked by inflectional suffixes (Maynard et al., 2018). In some languages the inflectional suffix conveys meaning of gender, by indicating feminine, masculine, or neuter properties of a noun (e.g. *hytt**a**/butikk**en**/tre**et*** respectively, in Norwegian). Number or quantity is indicated through the suffixation of nouns, which usually takes form as *-s* and *-es* in English (dog**s**/hero**es**), and *-er* and *-ene* in Norwegian (*bøk**er**/bøk**ene***). As can be noticed, inflectional suffixes in Norwegian also mark whether singular and plural nouns take on indefinite or definite form. The inflectional process further concerns verbs, where the suffix states the tense of the verb, by for example adding the suffix *-ed* in English and *-te* in Norwegian to indicate past tense in regular verbs (*walk - walk**ed***, *løp – løp**te***, respectively).

Derivational morphology regards the process of creating a new word from a stem morpheme, through the process of prefixation and suffixation (Feldman & Milin, 2018). The addition of one or more morphemes alters the meaning of the stem morpheme, and often changes the word class concurrently. For instance, the verb *explain* can be changed into the noun *explanation* by adding the suffix *-ation* (Kuo & Anderson, 2006). Hence, the process of derivation results in the formation of words that become distinct lexical entities (Feldman & Milin, 2018). Derivational morphemes are not as productive as inflectional morphemes, which entails that the rules applied in derivational processes are more consistent and restrictive (Gonnerman, 2018). This is noticeable in the way certain derivational morphemes are only attached to specific stem morphemes, such as the application of the suffix *-er* in English, which applies solely to verbs resulting in derived nouns (e.g. *teach-teacher*, *write-writer*). Or, by the way the suffix *-able* must be attached to verbs when forming adjectives (*read -readable, wash-washable*) (Gonnerman, 2018; Kuo & Anderson, 2006).

Compound morphology relate to words that are composed by two or more stem morphemes or words (inflected or derived), providing the compounded word with new sematic properties (e.g. *tooth* and *brush*, making *toothbrush*) (Fejzo, Desrochers, & Deacon, 2018). In English compound words are either attached (*football),* hyphenated (*empty-handed*), or detached (*ice cream*). Norwegian is a language that is more morphologically consistent than English, and compound words are always attached, often resulting in complex and long words that comprise several stems (Lyster et al., 2016), such as *bedriftshelsetjenesten* (the occupational health service).

2.2 What is Morphological Awareness?

In English and Norwegian, processes of inflection, derivation, and compounding generate morphologically complex words by combining morphemes in a rule-based manner. Children who are aware of such word structures and the rules they abide to can apply this knowledge to a variety of unfamiliar words (Sparks & Deacon, 2015). For example, children who know that the prefix *un-* implies the opposite of something, and that the stem *break* means to separate something, can decompose the complex and unfamiliar word *unbreak* into its morphemic units, and rely on morphological analysis to infer that the combination of the constituent word parts refer to an action that is the inverse of break, thus means to mend. Such an awareness of morphological structures facilitates word comprehension when contextual support is low (Carlisle, 2003). In line with this, morphological awareness can be defined as the ability to consciously reflect upon and manipulate morphemes, and the knowledge of how to apply word formation rules on linguistic structures (Kuo & Anderson, 2006, p. 161). In more general terms, morphological awareness is the knowledge of how to pair sound to meaning (Kuo & Anderson, 2006, p. 161). These definitions are essential and emphasise a conscious awareness of word formation rules that can be deliberately employed, hence, this description separates morphological awareness from the acquisition of morphology that takes place unconsciously in natural speech (Kuo & Anderson, 2006).

2.2.1 Developmental Trajectory

The development of morphological awareness is found to be lengthy and to progress in conjunction with the exposure to oral and written language (Kirby et al., 2012). A seminal study by Berko (1958) established that children already at the age of four had some awareness of basic inflectional rules. English-speaking children at the ages of four to seven were asked to produce corresponding grammatical changes in pseudo-words from syntactic demands (e.g. answering that a man who knew how to *zib* was *zibbing*). It was found that the participants were particularly capable of applying regular grammatical forms on demand, such as recurrently employed plural endings and present progressive regular verbs. Importantly, it was revealed that the school-aged children outperformed the pre-school children, which underscores that morphological awareness is subject to developmental growth across these ages. Although the finding was indicative of the presence of morphological awareness in pre-school children, it was shown that about 90% of the children were unsuccessful in the production of proper derived forms (e.g. answering that a man whose job was to *zib* is a *zibber*), suggesting that derivational awareness was preceded by inflectional awareness. This finding is consistent with other research, which indicates that inflectional awareness develops prior to formal reading instruction and is gradually acquired over the first school years (Berninger et al., 2010; Diamanti et al., 2018; Kuo & Anderson, 2006), while the awareness of derivational morphology arrives later (Kuo & Anderson, 2006), and seems to experience a substantial growth from the fourth grade onwards (Berninger et al., 2010).

There appears to be some variations in the development of morphological awareness across languages. For example, Chinese is a language rich of compounds and poor of derivations, and the awareness of compound morphology seems to precede that of derivational morphology in Chinese-speaking children (Ku & Anderson, 2003). In comparison, Greek is a language with a rich inflectional and derivational morphology, and it has been discovered that Greek-speaking children as early as the age of four have an awareness of inflectional and derivational morphology, albeit the latter seems to be present at a more intermediate (i.e. epilinguistic) level (Diamanti et al., 2018). There exists little research on the development of morphological awareness in Norwegian-speaking children. An exception is the experimental study by Ragnarsdóttir, Simonsen, and Plunkett (1999), which investigated the knowledge of past tense verb morphology in four-, six-, and eight-year-old Norwegian and Icelandic children. The study found that Norwegian children down to the age of four could inflect the largest category of past tense regular verbs (i.e. those inflected by the suffix *-et*), whereas smaller regular verb categories and irregular verbs were gradually developed, with most of them mastered between the ages six and eight, suggesting that inflectional awareness in Norwegian children largely follows the same progressive development over the first school years as is detected in other languages.

2.2.2 Terminological clarification

Morphological awareness is a complex area of research as morphology is closely related to other linguistic domains, which has led to an ambiguity of how morphological awareness is defined and understood (Gonnerman, 2018). According to a review by Apel (2014) there are inconsistencies that amount to insufficiencies with the current definitions of morphological awareness, presenting a need for a clearer theoretical framework. He claims that the variation of definitions has repercussions for how morphological awareness is operationalised, thus also for how the construct is measured. Consequently, inconsistent, and sometimes incorrect, data are used to draw conclusions (Apel, 2014). For instance has there been confusion as to how to separate the construct of morphological awareness to that of implicit morphological knowledge and morphological production (Apel, 2014).

As it is beyond the scope of this study to further engage with the unsettled terminology within the field of morphological awareness, it will be consequently referred to the conscious manipulation and analysis of morphemes as morphological awareness, based on the definition put forth by Kuo and Anderson (2006). The understanding will further rely on the description of morphological awareness as a metalinguistic ability building on the theory presented in the following section.

2.3 Morphological Awareness as a Metalinguistic Ability

Language development can largely be thought of in relation to two distinct, but closely connected, achievements; the first achievement regards the development of primary linguistic awareness such as understanding and producing language, while the second achievement concerns the manifestation of metalinguistic skills, which involves the ability to consciously manipulate linguistic structures (Nagy & Scott, 2000; Van Kleeck, 1982). Specifically, metalinguistics can be conceived as a subdomain of metacognition, which is the awareness and control of one’s own cognitive processes and strategies (Gombert, 1993). Morphological awareness is recognised as a metalinguistic ability, and has been described to transition from an implicit knowledge of word formation rules to more explicit and conscious levels (Carlisle, 1995). For example, young children reveal implicit morphological knowledge by the overgeneralisation of regular grammatical rules, such as inflecting the irregular verb *go* as *goed* in past tense as opposed to *went*, and by the production of neologisms through derivational and compounding processes. This productive use of morphology reflects an incomplete and developing understanding of linguistic rules, and cannot be ascribed to an explicit awareness (Carlisle, 1995).

Literature invested in the development of metalinguistic awareness has attempted to establish when linguistic knowledge transitions from an unconscious implicit level to an explicit level of awareness (Bialystok & Ryan, 1985; Carlisle, 1995; Diamanti et al., 2018; Gombert, 1992; Karmiloff-Smith, 1986). Gombert (1992) presented a model that sees the development of metalinguistic abilities to occur through four successive phases: (a) acquisition of first linguistic skills; (b) acquisition of epilinguistic control; (c) acquisition of metalinguistic awareness; and (d) automation of the metaprocess. The model begins with the acquisition of rudimentary linguistic knowledge that evolves throughout the phases to become more conscious cognitive control. The first phase involves simple levels of mastery both in terms of language production and comprehension, by which the child's inadequate use of language is regulated and stabilised by correction and reinforcement by an interacting adult. The second phase concerns the reorganisation of implicit knowledge as well as an extension of the child's knowledge. Gombert (1992) describes the last two levels of awareness as conditioned by the former phases. The third phase, the acquisition of metalinguistic awareness, regards a developing conscious control of various linguistic aspects. The final phase, the automation of the metaprocesses, comprises two processes: epi-processes, that occur unconsciously, and automated processes, that can be optionally replaced by meta-processes when required. Notably, the phases of metalinguistic awareness are believed to be recurrent and develop independently across linguistic domains (i.e. semantic, phonological, morphological). This means that children who have achieved an explicit awareness of phonology might still possess more implicit understandings of morphology (Duncan, Casalis, & Colé, 2009).

The levels of awareness postulated by Gombert have facilitated the understanding of morphological awareness as a construct constituted by two levels of awareness, namely epi-morphological and meta-morphological awareness (Diamanti et al., 2018; Diamanti et al., 2017). From this, it has been suggested that meta-morphological awareness should be measured by production tasks that require the production (i.e. manipulation) and retrieval of morphology in noncommunicative settings, in contrast to judgment tasks with no production demands that are believed tap epi-morphological awareness (Carlisle, 1995; Diamanti et al., 2018). The present study follows this operationalisation, and emphasises morphological awareness at the metalinguistic level.

2.4 Morphological Awareness and Language Processing

Morphological awareness as a metalinguistic skill involves cognitive abilities, and it is believed that this form of word learning relates to the organisation of the mental lexicon stored in long-term memory (Carlisle, 2007). There are, however, conflicting theories as to how the processing of morphological information occurs (Feldman & Milin, 2018, for a review); whereas one suggestion is that words are stored in the mental lexicon by their stems, with affixes to be attached by rules of word formation (Taft & Forster, 1975), others propose that the processing of complex words concerns a whole-word storage for irregular words and a rule-based decompositional storage for regular forms (Clahsen, Sonnenstuhl, & Blevins, 2003). It has for instance been suggested that irregular word pairs that undergo changes in the stem (e.g. *overrun-overran*) are non-compositional and demands whole word retrieval from lexical memory, while words that are governed by regular formation rules (e.g. *overuse-overused*) are eligible to be decomposed and understood by applying rules of word formation (Carlisle, 2000; Feldman & Milin, 2018). Further suggestions have been made that word structure is not sufficient to how well words are represented in memory, but that exposure and transparency of words also matters (Carlisle, Stone, & Katz, 2001; Reichle & Perfetti, 2003). This can be corroborated by the way some words are orthographically transparent but semantically opaque (e.g. *apply-appliance*) suggesting that morphological analysis alone is inept to provide meaning (Carlisle & Nomanbhoy, 1993; Reichle & Perfetti, 2003). A recent cross-linguistic study by Mousikou et al. (2020) explored whether it was the morphological complexity of words or orthographic transparency that determined the reliance on morphological analysis during online reading. The study looked at the ability of 126 Grade 3 children and of 128 adults to read real words and pseudo-words aloud in English, French, German, and Italian. The languages were chosen based on their differences in orthographic transparency and morphological complexity, to which English is recognised as more orthographically opaque and less morphologically rich than the other languages included. The results showed that the English participants relied more on morphological analysis while reading than did the other groups, after controls of reading ability and vocabulary, indicating that morphological processing was more involved when reading words with inconsistent letter-sound correspondences than when encountering morphologically complex words.

2.4 The Importance of Morphological Awareness to Language and Literacy Skills

Morphological awareness is fundamental to word recognition, and a variety of research has established that morphological awareness is a unique contributor to vocabulary growth (McBride–Chang et al., 2005; Sparks & Deacon, 2015; Spencer et al., 2015). Vocabulary knowledge is tied to reading achievement, and morphological awareness has correspondingly been recognised for its impact on a variety of literacy skills, including abilities such as decoding, reading fluency, and reading comprehension (Carlisle & Nomanbhoy, 1993; Deacon & Kirby, 2004; Duncan, 2018; Mahony, Singson, & Mann, 2000; Nagy, Carlisle, & Goodwin, 2014). These findings have further proven to be consistent across orthographies (Diamanti et al., 2017; Kim, Guo, Liu, Peng, & Yang, 2019; Kuo & Anderson, 2006; Lyster et al., 2016). The significant role of morphological awareness to literacy has been found to be robust to a variation of control measures, and morphological awareness has been able to uniquely explain a larger variance in reading comprehension than phonological awareness, which is contradictory to the long belief of phonological awareness as the most influential skill to reading abilities (Nagy et al., 2014, for a review). For example, a longitudinal study conducted by Diamanti et al. (2017), uncovered that morphological awareness in Greek pre-school children uniquely predicted word accuracy, pseudo-word accuracy, reading comprehension, and spelling in Grade 1, beyond the influence of phonological awareness, and expressive and receptive vocabulary, accounting for a variance of 9-14% depending on the outcome measure. Furthermore, a four year longitudinal study by Deacon and Kirby (2004) provided similar findings in older English-speaking children. The study employed regression analyses with autoregressive controls to compare the role of Grade 2 morphological awareness to that of phonological awareness in reading development throughout Grades 3-5. The results revealed that morphological awareness contributed significantly to pseudo-word reading and reading comprehension in Grades 4 and 5, beyond the influence of phonological awareness. However, the prediction of morphological awareness to Grade 3 reading outcomes proved insignificant, implying that the role of morphological awareness to literacy in English-speaking children increases across grade levels.

The contribution of morphological awareness to reading abilities has moreover been evidenced in experimental intervention studies (Bowers et al., 2010, for a review; Carlisle, 2010; Lyster, 2002; Lyster et al., 2016). A systematic literature review by Bowers, Kirby and Deacon (2010) of twenty-two studies concerning the influence of morphological instruction on literacy revealed that morphological instruction benefits reading abilities, and interestingly, that instruction particularly is beneficial for less able readers. Variation in cognitive and linguistic development is tied to language-learning abilities, and it is reasonable to assume that these variations affect an individual's metalinguistic reasoning (Carlisle, 2007). For example, a study by Zhang and Shulley (2017) investigated the ability poor reading comprehenders - with intact word reading skills - had in employing morphological analysis during sentence reading. The sample consisted of eighty-one Grade 4 and 5 students, who were either English only speakers or English language learners. The results indicated that the poor comprehenders were less able to utilise morphological analysis to infer meaning during sentence reading compared to the control group of typical readers.

Based on empirical research it is evident that morphological awareness is imperative to vocabulary growth and literacy development; both in typically developing children and in children who face challenges in their language and reading development. This makes it important to explore the underlying cognitive mechanisms by which morphological awareness facilitates these language and literacy achievements. In line with this, the next chapter intends to present theoretical standpoints and empirical findings within the field of working memory.

3. Theoretical and Empirical Background: Working Memory

3.1 What is Working Memory?

Whereas research on the nature of memory dates back two centuries, research on working memory has proliferated the last decades. The field of working memory is complex, and plentiful studies have attempted to conceptualise working memory in order to understand its relations to other abilities (e.g. Atkinson & Shiffrin, 1968; Baddeley & Hitch, 1974; Broadbent, 1958; Cowan, 2008; Engle, 2002). Empirical findings on working memory have provided insights to mechanisms driving individual cognitive development, and lately research has been interested in the relation working memory capacity has to developmental disorders (Archibald & Gathercole, 2006; Jackson, Leitao, Claessen, & Boyes, 2019; Pickering, 2006; Pickering & Gathercole, 2004). It has consequently been established that children's ability to store and manipulate information is paramount to skills involved in scholastic attainment, leading research to prove significant relations between working memory and a variation of language and literacy skills (Daneman & Carpenter, 1980; Fitzpatrick & Pagani, 2012; Gathercole et al., 2003; Gathercole, Willis, Emslie, & Baddeley, 1992; Johann et al., 2019; Kidd, 2013; Newbury et al., 2016; Verhagen & Leseman, 2016).

The working memory construct has evolved from theories on short-term memory (Baddeley, 2003). A traditional perception of short-term memory was that of a passive system intended for the temporary storage of memory traces, in which memory traces were subject to be rapidly lost due to decay (Atkinson & Shiffrin, 1968). Working memory was developed out of recognition that memory served a more active role in the processing of concrete and abstract information (Cowan, 2014). Historically, the exact nature of working memory has been hypothesised by a variation of models (Atkinson & Shiffrin, 1968; Baddeley, 2000; Baddeley & Hitch, 1974; Broadbent, 1958; Cowan, 2008). Some early suggestions saw working memory as a two-component model (Atkinson & Shiffrin, 1968; Broadbent, 1958). The perhaps most influential two-component model was proposed by Atkinson and Shiffrin (1968), who recognised information to be entered via a sensory register to the short-term store, where it was temporarily retained before being entered to a more durable long-term store. According to this model, learning occurred when sensory information was rehearsed (i.e. repeated) and transferred from the short-term component to the long-term component.

Notably, it was short-term memory that served the role as working memory, and Atkinson and Shiffrin described this domain to be involved in resolving complex tasks such as reasoning and comprehension. It was subsequently recognised that individuals with short-term memory deficits were able to master complex cognitive tasks despite their limitations, which suggested there had to be a separate working memory involvement (Baddeley, 2000, 2003; Baddeley & Hitch, 1974). This led to the proposition of working memory to be more than a unitary short-term store, but rather a complex system holding separate interacting components (Baddeley, 2012; Baddeley & Hitch, 1974; Cowan, 2001, 2008).

Although there currently is a wide theoretical consensus of working memory as a multifaceted construct, there are to date conflicting suggestions on the nature of working memory. Cowan (2014) considers working memory to be the temporary activation of areas embedded in long-term memory, where attentional control is the core of the model. On the other hand, Engle (2002) suggests that working memory is not related to memory *per se*, but contrarily to the ability to convey attention in order to maintain or suppress information. In this view, a greater working memory capacity is not reflected by a greater memory store, but rather by an increased capacity to control attention. The majority of working memory research has nonetheless been influenced by the multi-component model initially proposed by Baddeley and Hitch (1974) and later revised by Baddeley (2000). This model has been identified to be best suited in explaining working memory in children (Alloway, Gathercole, Willis, & Adams, 2004; Giofrè, Mammarella, & Cornoldi, 2013), and has therefore been chosen to guide the understanding of working memory in this study. The multi-component model will be presented in the following.

3.2 The Multi-Component Model

Based on the earlier two-component models (Atkinson & Shiffrin, 1968; Broadbent, 1958), Baddeley and Hitch (1974) postulated a multi-component model of the working memory that contrasted itself from the preceding models by its proposition of the working memory system as complex cognition beyond pure memory (Baddeley, 2000). Baddeley and Hitch proposed working memory to be a limited central executive system in control of two temporary storage systems that in combination served to facilitate performance of multiple complex tasks (Baddeley, 2003; Baddeley & Hitch, 1994). Accordingly, the multi-component model includes a *central executive component*, functioning as an attentional control system to rule the subsidiary slave systems *the phonological loop* and *the visuospatial sketchpad.* The initial model has later been revised by Baddeley (2000) to comprise a third slave system, namely *the episodic buffer*.

3.2.1 The Central Executive

The central executive component is a flexible but limited resource that is monitoring a variety of high-level cognitive functions. It is described as the most complex component of the working memory, and it is believed that the component can be fractioned into several subprocesses (Baddeley, 1998; Baddeley & Hitch, 2000). Firstly, the component has been recognised by its more general control functions, such as the control of the flow of information through working memory, the retrieval of material stored more permanently in long-term memory, and the control of actions, planning, and goal-directed behaviour (Pickering & Gathercole, 2001). Secondly, the component has been identified to be in control of more specific strategies, such as shifting attention between tasks, sustained attention, inhibition (i.e. focus of attention through the blockage of irrelevant stimuli), updating (renewing and monitoring the contents in working memory), and mental flexibility (Baddeley, 2003, 2012).

3.2.2 The Phonological Loop

The phonological loop is a verbal storage system, and holds information based on its phonological qualities (Baddeley, 2003). The system has two features, designated as a temporary phonological store where memory traces decay after few seconds, and a subvocal rehearsal process that occurs in real-time to restore and maintain decaying items (Baddeley, 2003, 2010; Baddeley & Hitch, 1974). Information of auditory nature is subject to gain direct access to the phonological store, while visual representations, such as printed words, can be indirectly entered to the phonological store through subvocalisation (i.e. mapping images to internally generated phonological codes) (Baddeley, 2000; Gathercole, 1998). This entails that visual items can only be encoded insofar as they can be named.

3.2.3 The Visuospatial Sketchpad

The visuospatial sketchpad component was based on the recognition that verbal and visuospatial working memory involved distinct resources (Baddeley & Hitch, 1994).

The sketchpad concerns the short-term storage of visual and spatial information, and plays an important role in generating and manipulating visual images. It has additionally been suggested that the visuospatial sketchpad can temporarily store tactile information, stemming from, for instance, the touching of an object (Baddeley, 2012).

3.2.4 The Episodic Buffer

The episodic buffer allows information from the phonological loop and visuospatial sketchpad components to be joined with long-term memory representations, resulting in episodic representations in the form of integrated chunks (Baddeley, 2000). It is further believed that the episodic buffer forms a foundation for conscious awareness (Baddeley, 2000, 2003).

3.3 Defining Working Memory

Following Baddeley, working memory is referred to as a multi-dimensional system important for performing complex tasks such as reasoning, comprehension, and learning (Baddeley, 2010, p. 136). Moreover, working memory is a cognitive construct with a finite capacity, that regards the concurrent preservation and manipulation of information (Baddeley, 2000, p. 418). As acknowledged, the working memory construct is distinct from long-term memory, yet their relations cannot be ignored. While working memory is represented by fluid systems that relies solely on temporary activation, long-term memory holds crystallised skills and knowledge of a more permanent character (Baddeley, 2012). Baddeley (2012) congruently describes working memory to control components of the brain that interact with long-term memory representations.

Measurements of working memory capacity typically involve tasks where subjects are expected to temporarily hold and recall information while simultaneously perform another attention demanding task (Daneman & Carpenter, 1980; Pickering & Gathercole, 2001). Notably, working memory tasks show higher correlations with high levels of cognition than that of simple recall tasks used to tap short-term capacity (Engle, 2002, for a review). In accordance with this, working memory capacity is defined as an individual's temporary storage limits *and* the individual's ability of high-level executive processing (Baddeley & Hitch, 1974; Cowan, 2008; Daneman & Carpenter, 1980).

3.2.1 Developmental Trajectory

Working memory undergoes a developmental capacity growth in line with age or mental age (Henry & Millar, 1991; Mathy & Friedman, 2020). Children seem to acquire an adult model of working memory around the age of six, and each working memory component appear to expand its capacity throughout early and middle childhood into adolescence (Gathercole, Pickering, Ambridge, & Wearing, 2004). Gathercole et al. (2004) investigated working memory development in 736 children spanning the age of 4 to 15. They found that the capacity of each working memory component – the central executive, the phonological loop, and the visuospatial sketchpad - increased linearly from the age of 4, with strong correlations between the components throughout development. Albeit the working memory components seem to have an integrated development, it has been identified that the phonological loop and the visuospatial sketchpad develop independently from each other, which underlines their roles as distinct domains (Gathercole et al., 2004). Additionally, there seems to be a shift around the age of seven; prior to this age children are generally unsuccessful in subvocal rehearsal, which leads them to rely more on the memorisation of stimuli based on their visual characteristics (Gathercole, 1998).

3.2.1 Terminological Clarification

In the literature the terms working memory and short-term memory are commonly used interchangeably, which stems from working memory's evolution from the term short-term memory. The present study will use the term short-term memory in occasions where it is being referred to the temporary storage of information, while the term working memory will refer to the storage and manipulation of information, building on the multi-component model by Baddeley and Hitch (1974), and Baddeley (2000, 2003, 2012). The term verbal working memory will be used to refer to the storage and manipulation of verbal information, whereas verbal short-term memory will refer to the phonological short-term store (Kidd, 2013, p. 208).

3.3 The Role of Working Memory in Language and Literacy Acquisition

Early language abilities relate to working memory capacity. A longitudinal study by Newbury et al. (2016) investigated patterns of language development in seventy-seven toddlers, and found early verbal working memory capacity in two-year-olds to significantly predict expressive and receptive language measured 18 months later, indicating that verbal working memory with a large capacity was an advantage for the pre-school children during their early language development. Similar findings have been substantiated by others (Fitzpatrick & Pagani, 2012; Stokes, Klee, Kornisch, & Furlong, 2017). Nevertheless, the extent by which working memory components take part in language processing throughout developmental years remains unclear (Engel de Abreu, Gathercole, & Martin, 2011). Working memory capacity has been found to be a better predictor of language comprehension than short-term store capacity (Daneman & Merikle, 1996, for a review), which might relate to the fact that comprehension depends on an active use of knowledge, which in turn relies on high-order cognition, such as reasoning and attention through the inhibition of irrelevant information (McVay & Kane, 2012; Zhang et al., 2014). This notion seems to be consistent with a meta-analysis conducted by Peng et al. (2018) that set out to explore the associations between working memory and reading. They identified that a domain-general working memory (i.e. central executive) was largely involved in early reading acquisition prior to Grade 4, and more specifically, that working memory provided a stronger correlation to reading comprehension before fourth grade than beyond this grade. This could imply that children who have not yet completely mastered foundational reading skills, are reliant on working memory for attentional processes demanded by decoding and comprehension. Comparably, children at later grade levels were found to more efficiently decode and infer meaning based on their expanded verbal knowledge, and therefore used more domain-specific areas of working memory, thus to a smaller degree strained the central-executive whilst reading. In addition, a study by Engel de Abreu et al. (2011) found that short-term memory and cognitive control - measured by complex span tasks tapping the central executive - related to distinguishable language achievements in six-year-old children. It was identified that the short-term storage related to vocabulary knowledge, whereas cognitive control, on the other hand, provided specific links to receptive grammar and reading abilities, distinct from short-term storage, rhyme awareness, and vocabulary. Based on the results, the authors argue that cognitive control is required to support higher order linguistic tasks that demand a concurrent regulation and coordination of information.

It has moreover been suggested that children seem rely on the phonological store at a very young age, leading the phonological loop to be accredited a fundamental language-learning device that contributes to vocabulary growth in early childhood (Engel de Abreu et al., 2011; Gathercole, 1998; Gathercole et al., 1992). It has particularly been suggested that nonword repetition tasks are reliable measures of phonological loop capacity, hence also the ability of vocabulary learning (Baddeley, 2000). Nonword repetition tasks are considered appropriate measures as they are believed to tap the capacity of novel word learning, beyond the reliance on long-term lexical representations (Baddeley, Gathercole, & Papagno, 1998). It has for example been identified that children with developmental language disorder have nonword-repetition deficits (Jackson, Leitao, & Claessen, 2016). These findings are, however, at odds with a longitudinal study by Melby-Lervåg, Lervåg, et al. (2012), which found no evidence to support that abilities of nonword-repetition in four-year-old children predicted later vocabulary knowledge. As such, the function of the phonological loop in early language acquisition seems unclear.

3.3.1 Working Memory and Language Processing

In addition to nonword repetition, measures of the phonological loop typically involves serial recall tasks of real words and digits intended to tap short-term memory capacity (e.g. Pickering & Gathercole, 2001). It has been recognised that children tend to perform better at recalling real words compared to nonwords, high-frequent words to low-frequent words, as well as concrete words to more abstract (Majerus & Van der Linden, 2003). It has therefore been suggested that success in recall tasks depends on how accessible lexical and semantic representations are in long-term memory (Majerus & Van der Linden, 2003; Melby-Lervåg & Hulme, 2010; Roodenrys, Hulme, & Brown, 1993). Accordingly, considerable attention has been directed to the possible role of long-term memory in the achievement in such tasks (Ellis & Sinclair, 1996; Gathercole, 1998; Roodenrys & Hinton, 2002; Roodenrys et al., 1993; Thalmann, Souza, & Oberauer, 2019). Some have identified that short- and long-term memory interaction is bound to a redintegration process, in which incomplete phonological items are reconstructed by stored knowledge of lexical, semantic, and phonological properties (Gathercole, 1999; Roodenrys & Hinton, 2002; Roodenrys et al., 1993).

In line with this, it has been proposed that the recoding of small units of information into larger units, denoted as chunking, frees up short-term memory capacity and reduces the load on working memory (Chen & Cowan, 2005; Cowan, 2001; Miller, 1956; Norris, Kalm, & Hall, 2019; Thalmann et al., 2019). This notion is based on the recognition that individuals are able to retain sequences of numbers, letters, and words exceeding their short-term memory capacity (Thalmann et al., 2019). Chunking concerns long-term representations of familiar units (Thalmann et al., 2019), and necessitates the episodic buffer, as this component integrates episodic representations as chunks while also being a pathway to long-term representations (Baddeley, 2010, 2012). Following Norris et al. (2019), the recoding of information involved in chunking can be seen as a form of data compression, in which stored information takes up less capacity than the input. A typically presented example is that the letter sequence F-B-I-C-I-A would prove less demanding to keep in short-term term memory by its likeliness of being processed as familiar chunks (i.e. FBI, CIA), than other sequences of arbitrary letters (Cowan, 2008). Miller (1956) was the first to postulate the process of chunking. He suggested that the capacity of short-term memory was not restricted by the amount of information that could be held, but rather by the amount of chunks, and hypothesised that the short-term memory had a capacity limit of approximately seven chunks. A more recent proposal is that the capacity of the short-term memory is about four chunks (Baddeley, 2010; Cowan, 2001). Thalman, Souza, and Oberauer (2019) conducted experiments on twenty adults to examine the benefits of chunking on working memory, and their study shows some valuable findings. In particular, it was established that the participants who were able to chunk information freed their working memory capacity, which in turn made it easier to memorise not-chunked information. For instance, chunking FBI in the letter list F-B-I-D-Q-B, made it easier to retain the last letters D-Q-B. Additionally, they discovered that a chunk comprising more than three letters exceeded the working memory load to that of a single letter, which suggested that chunk size mattered to how well the participants could memorise sequences.

In terms of language acquisition, it would seem likely that working memory concerns the processing and retention of language sequences as chunks (Ellis & Sinclair, 1996). The process of chunking is therefore of importance to the present study as it might provide some understanding of how limitations in working memory could affect the ability to decompose and store linguistic components in memory which, in turn, could affect language acquisition and comprehension.

3.5 The Importance of Working Memory to Language and Literacy Skills

Working memory has been identified to uniquely predict a variety of language skills, such as receptive vocabulary (Fitzpatrick & Pagani, 2012; Newbury et al., 2016), grammatical skills (J. L. McDonald, 2008; Verhagen & Leseman, 2016), and phonological awareness (Berninger et al., 2010; Oakhill & Kyle, 2000), as well as literacy outcomes, such as reading speed (Johann et al., 2019), reading comprehension (Gathercole et al., 2003; McVay & Kane, 2012; Peng et al., 2018), and spelling (Gathercole et al., 2003). Lastly, working memory has been noticed to be a predictor of overall early academic skills (Gathercole et al., 2003; Montoya et al., 2019). For instance did measures of working memory in British children at the age of 4 or 5 serve as excellent longitudinal predictors for achievements in national assessments of academic abilities, measured up to 3 years later (Gathercole et al., 2003). Similar results have been shown in younger children; Fitzpatrick and Pagani (2012) found working memory in toddlers to be predictive of kindergarten school readiness. The study included 1824 children who were assessed on working memory capacity when they were 29 months and 41 months old. Outcome measures were receptive vocabulary, number knowledge, and overall classroom engagement measured at 74 months old, and regression analyses revealed that working memory significantly and uniquely related to all of the outcomes, beyond verbal and nonverbal intellectual abilities.

Moreover, limits in working memory capacity relate to developmental disorders (Henry & Botting, 2017; Jackson et al., 2016; Ullman et al., 2020). For example, a systematic review by Henry and Botting (2017) reported evidence that working memory limitations in children with developmental language disorder stemmed from limitations in the central executive domain, along with a restricted phonological short-term store. Due to relations between working memory limitations and neurodevelopmental conditions, a long history of research has examined how working memory capacity can be improved through experimental intervention studies (Melby-Lervåg & Hulme, 2013, for a review). While interventions targeted at improving working memory have found some direct effects upon working memory capacity (Siu, McBride, Tse, Tong, & Maurer, 2018), the generalised effect to other linguistic skills has proven to be limited. In particular, a meta-analytic review by Melby-Lervåg and Hulme (2013) looked at twenty-three experimental studies, and found limited evidence of durable transfer effects of working memory training to other linguistic skills. This suggests that although working memory proves to be an excellent predictor to a range of skills, its training serves a restricted clinical value. However, the same authors conducted a training study which evidenced that linguistic instruction, such as training of phoneme-awareness and vocabulary, had transfer effects to performance in recall tasks employed to tap verbal short-term memory (Melby-Lervåg & Hulme, 2010). This would support a bidirectional relationship, in which working memory capacity depends upon stored linguistic knowledge.

According to the presented empirical evidence, it can be recognised that working memory is successful in predicting a variety of language and literacy skills, indicating that the capacity of working memory is closely tied to a variation of achievements. The following chapter will present existing research on the relationship between working memory and morphological awareness, and thereafter summarise key points from the theoretical chapters in the rationale (section 4.2).

4. Working Memory and Morphological Awareness

4.1 Research on Working Memory and Morphological Awareness

There exists little research to have explicitly related morphological awareness to working memory, however, some studies have explored the associations between working memory and more implicit morphological knowledge (Daneman & Case, 1981; J. L. McDonald, 2008; Verhagen & Leseman, 2016). These findings seem consistent in showing that some links between the two constructs are present. For example, the study by J. L. McDonald (2008) considered the role of age, working memory, and phonological ability in the grammaticality skills of 68 six- to eleven-year-old children, and of 19 adults. The participants were asked to judge ten different grammatical constructions, such as regular plurals, regular past tense, and irregular past tense. The results indicated that all the constructions of regular verb morphology errors - in particular past tense verbs, and third person agreement – placed high demands on working memory processing.

An earlier study by Daneman and Case (1981) identified that short-term memory was predictive of the acquisition of an artificial language. Children aged between two and six were presented with novel actions and novel labels for these actions. The pseudo-words to represent the actions were stems (*pum*) that had been inflected by either a suffix (*pum**abo***), a prefix (***aki**pum*), or both (***a**pum**tay***). At post-test, in which the children had to both produce the appropriate labels to go with the actions and to pair the actions to their respective labels, it was found that the morphological complexity of the pseudo-word was influential to how easily the words were processed; it was, for instance, easier to produce *pum-abo* than *a-pum-tay.* The authors suggested that this could be rooted in the fact that the words with split affixes on either side of the stem required to be retained in short-term memory as three separate chunks, while the words that consisted of two contiguous parts were more likely to be encoded as a single chunk, and therefore imposed less working memory load.

A relation between working memory and more explicit levels of morphological awareness seems to have been detected by Verhagen and Leseman (2016), who explored the relationship between verbal working memory and the acquisition of grammar in five year old

Dutch monolingual children, and in five year old Turkish children who were learning Dutch as a second language. The study used production tasks to tap grammaticality skills, in which the children were asked to produce noun plural endings, and to inflect verbs in the past participle by syntactic cues (e.g. "Rosita is throwing a ball. Yesterday she has also… [*thrown*] a ball"). Structural equation modelling showed that verbal working memory, as well as verbal short-term memory, were significant predictors of the grammar measures in both child groups. The correlation between verbal short-term memory and language learning might suggest that a well-functional phonological store allows for words to be retained in order to be analysed and reflected upon, and subsequently stored as long-term representations in the form of sounds (i.e. phonemes), but perhaps also as larger chunks (morphemes), to be retrieved for the comprehension and acquisition of novel words (Verhagen & Leseman, 2016).

A study by Mainela-Arnold, Misra, Miller, Poll, and Park (2012) showed that the ability 6- to 13-year-old children had in segmenting linguistic structures was a significant predictor to how well they performed in a sentence-span task. An Elision task was employed to tap segmenting skills, in which the children were asked to decompose words by constituent phonemes (e.g. "say tan without the /t/"), and to decompose compound words by constituent stems (e.g. "say popcorn without saying corn"). A complex sentence-span task was employed to tap working memory capacity, in which the children were asked to judge sentences' veracity by answering "yes" or "no" and subsequently recall the final word of each heard sentence. Based on the significant association between the Elision task and the sentence-span task, the authors suggested that the sentence-span task demanded metalinguistic ability in the form of decomposition skills, and that metalinguistic abilities therefore in part determined individual achievement in such a working memory task. In the study it was accordingly argued that the relationship between working memory capacity and linguistic knowledge is of a circular, rather than causal, character, and that clinical interventions therefore should aim at building language skills, which consequently could improve working memory processing.

4.1.1 Proposed Model of Working Memory and Morphological Awareness

The first, and seemingly only, in the literature to have explicitly related morphological awareness to working memory is Zhang, Lin, Wei, and Anderson (2014), who suggested that the contribution of morphological awareness to reading comprehension involves working memory. Based on established empirical and theoretical links between morphology and working memory, the authors propose a model (see Figure 1) that builds on Baddeley's working memory model to show hypothesised links between working memory, morphological awareness, vocabulary learning, and reading comprehension. As outlined in the paper, the model is based on some premises, which are: (a) the ability to deconstruct morphological complex words makes word learning more efficient; (b) word learning is incidental, meaning that morphological awareness is fundamental when inferring meaning from words where contextual support is low (i.e. during listening and reading); and that (c) morphological awareness increases the efficiency of verbal working memory by chunking meaningful units within unfamiliar words (Zhang et al., 2014, pp. 4-5). Within the model, the components have dynamic relations, and it is suggested that morphological awareness directly involves the central executive by attentional demands tied to metalinguistic awareness, in which attention is required for the decomposition and analysis of morphemic structures. It is moreover suggested that the episodic buffer is necessitated for integrating long-term representations with temporarily stored phonological and visual information, in the form of morpheme-sized chunks. The model further reflects the dynamic relationship between morphological awareness, vocabulary, and reading comprehension. While the model lacks pre-existing empirical support, Zhang et al. suggest that such research should be carried out, as a support for the model would strongly suggest that morphological instruction could benefit working memory capacity. The rationale within this study that is invested in the role that working memory has in the development of morphological awareness could thus be a preliminary attempt to reveal whether or not such a model can be supported.

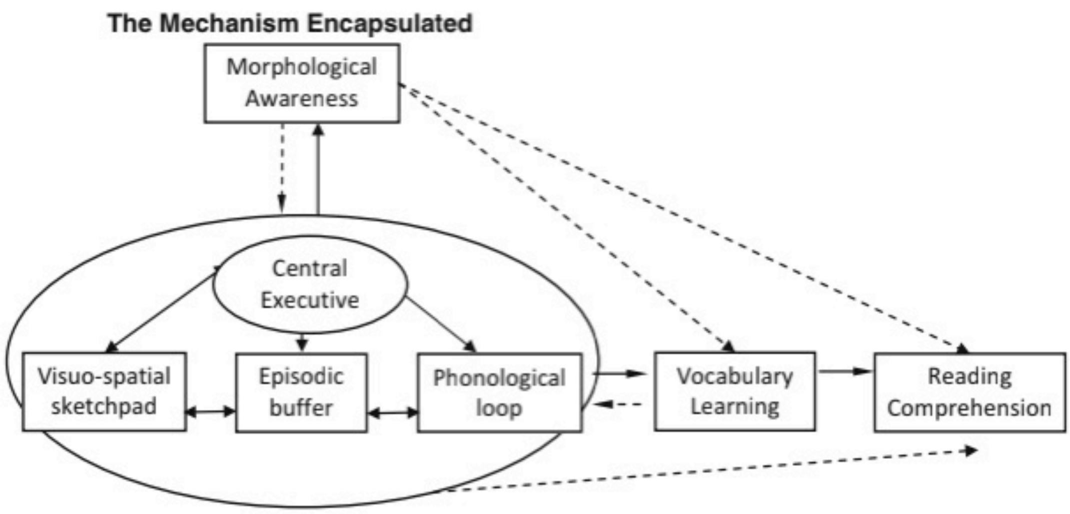

Figure 1. *Proposed model: Working memory, Morphological Awareness, and Reading*

(Zhang et al., 2014, p. 16)

4.2 Rationale of the Present Study

While Chapter 2 and 3 of the present study have presented the theoretical and empirical background of morphological awareness and working memory, respectively, the present chapter has outlined existing research on morphology and working memory. Based on these chapters some points should be made.

Firstly, working memory has been shown to be an excellent predictor to a wide array of skills, such as vocabulary, literacy, and school achievement in general. The presented research has emphasised that chunking of information reduces working memory load, which in turn makes it easier to learn non-chunked material. Moreover, the central executive seems to be an important contributor to reading comprehension due to the attentional demands this reading skill poses. Secondly, research highlights that morphological awareness is a metalinguistic skill that allows children to efficiently analyse and decompose morphologically complex and opaque words, and substantial evidence supports the role of morphological awareness in building meaning from oral and written contexts. Thus, strong links have been proven between morphological awareness, vocabulary knowledge, and literacy abilities, yet there exist limited knowledge about the underlying cognitive mechanisms that facilitate these achievements. Based on the model by Zhang et al. (2014) it can be hypothesised that working memory, morphological awareness, vocabulary, and reading comprehension are in an interacting relationship, however no research has so far empirically investigated this.

Having outlined the limitations between the research fields of morphological awareness and working memory, as well as the importance of both abilities to developing children, the present study intends to answer the following research question:

Does working memory predict the development of morphological awareness over time?

5. Method

The purpose of this study is to examine the role working memory has in the development of morphological awareness. The study within this thesis is written in association with the research project "NumLit – Development of Numeracy and Literacy in Children", and will use data obtained from three waves of measurement.

5.1 Longitudinal Design

The present study is non-experimental, which means that it aims to describe the state of something, as opposed to manipulate variables through interventions (Kleven, 2002b). The *NumLit* project follows the same sample of children from the age of 5 until the age of 18, and is therefore a longitudinal panel study (Gall, Gall, & Borg, 2003). The longitudinal design provides the opportunity to investigate how various traits and skills develop and correlate intra- and inter-individually (Creswell & Creswell, 2018; Gall et al., 2003). Additionally, a longitudinal study can facilitate the making of inferences about the predictability of one variable upon another. In the present study, the longitudinal design enables the exploration of the possible role working memory capacity in pre-school has for the development of morphological awareness across Grades 1 and 2.

5.2 Sample

The sample consists of 216 children, who all participated in the three waves of measurement in the *NumLit* project. The children were born in 2012, all of whom were 5-years-old during the first wave of data collection (M = 66.2 months, SD = 3.8). At the first wave participants attended their final year of kindergarten, at the second wave they attended grade 1, and at the third wave they attended grade 2. Each year the children were assessed between the months of January to March. All the participants are native Norwegian speakers, and do not have any diagnosed neurological or developmental disorders. The sample was recruited from various pre-schools situated in four municipalities enclosing Oslo. This area was selected as it is believed to represent a broad range of the population in terms of socio-economic conditions. Kindergarten personnel recruited the children at the start of the project; the parents were provided information about the project and were asked if their child could participate. Written consents were thereafter collected from the parents, as well as oral assents from the children.

5.3 Data Collection

The data have been collected annually, and there have been three waves of measurement. The *NumLit* test battery is extensive, and consists of subtests taken from standardised test-batteries and of tests developed especially for *NumLit*. For the procedure of collecting the data, the test-battery was divided into three sessions for Time 1 and Time 2, and four sessions for Time 3. The test sessions for each child took place on separate days, and were at least two days apart. Each assessment lasted for approximately 45-90 minutes per child, and the children were tested in a separate and quiet room at their pre-school for Time 1, and at their school for Time 2 and Time 3. Breaks were provided if needed. The children received diplomas on each occasion, and after each completed task the child chose a sticker to attach to the diploma.

The data were collected by thoroughly trained research assistants at master's level. The assistants all attended the University of Oslo, and belonged to either The Department of Special Needs Education, The Department of Education, or The Department of Psychology at the time of data collection. The tests were either scored during the assessment, or after. Some of the tests were computerised, and they were scored automatically. All the test sessions were audio recorded, which functioned as an assurance for the children and their parents. In addition, the audio recordings made it possible for the test administrator, as well as the research group, to relisten to the assessments insofar as there were any uncertainty related to the administration or scoring of the tests.

5.4 Data Analysis

This is a quantitative study that relies on numerical data, and in accordance with this statistical analyses will inform the interpretation of the results. This study will use correlational statistics to reveal the strength of the association between working memory and morphological awareness. To explore the longitudinal prediction of working memory upon morphological awareness, two hierarchical multiple regression analyses will be employed: the first analysis aims to examine the possible effects of pre-school working memory upon morphological awareness in Grade 1, while the second analysis will examine the possible effects of pre-school working memory upon morphological awareness in Grade 2.

Multiple regression allows the exploration of the relative contributions of multiple predictor variables on an outcome variable (Roever & Phakiti, 2018). The hierarchical aspect of the regression enables the control of possible confounding variables by entering the variables in prioritised order. In turn, this reveals both the unique and shared variance explained in the outcome variable by each predictor variable at its point of entry in the analyses (Tabachnick & Fidell, 2014). Nonverbal-IQ and receptive vocabulary will be entered as predictors in the regression models, and statistically controlled for. Receptive vocabulary, that is, the amount of words a person can comprehend (Burger & Chong, 2011), is chosen as a control variable due to its recognised associations with morphological awareness. Nonverbal-IQ, denoted as general intellectual functioning without verbal constraints (Yarian, Washington, Spencer, Vannest, & Crowe, 2019), is chosen as this study intends to explore the prediction of working memory upon morphological awareness beyond the impact of more general cognitive abilities. It will additionally be controlled for the autoregressive effects of pre-school morphological awareness. The autoregressive controls will be employed to eliminate the risk of identifying a significant relationship between working memory and Grade 1 or Grade 2 morphological awareness that might be due to interactions at pre-school level (de Jong & van der Leij, 2002); the reported effect in this study will thus be attributable to the growth in morphological awareness from the first grade onwards (Parrila, Kirby, & McQuarrie, 2004). From the statistical controls, inferences can be made about the unique variance in morphological awareness accounted for by working memory, above and beyond the autoregressor, nonverbal-IQ, and receptive vocabulary.

The analyses will be run in the statistical analysis program IBM SPSS Statistics for Macintosh, version 26.0 (IBM, 2019), with the exception of Revelle's omega total, which will be estimated in the statistical analysis program Jamovi, version 1.2 (The Jamovi Project, 2020).

5.5 The Variables and Their Measurement Tools

In statistical analysis various terms are commonly used to describe and distinguish between variables. Perhaps most common are the terms independent and dependent variable, in which the independent variable can be described as the predictor variable and the dependent variable as the predicted, or outcome, variable (L. Cohen, Manion, & Morrison, 2007). Because this is a study that seeks to examine associations through regression, the term predictor variable will be used for each of the independent variables, and the term outcome variable will be used to describe the dependent variables.

All of the predictor variables employed in this study have been measured in pre-school. Morphological awareness is the outcome measure for both regression analyses, thus has also been measured in Grade 1 and Grade 2. The constructs of interest and the variables they are operationalised by (i.e. tests) are presented in Table 1, and described in more detail in the following sections.

Table 1. *The Constructs and Their Measurement Tools*

Construct	Measures/Variables	Test battery
Morphological awareness	Meta-inflectional Production Task	
	Meta-derivational Production Task	
Working memory	Backward Digit Recall	WMTB-C
	Listening Recall	WMTB-C
Nonverbal-IQ	Matrix Reasoning	WPPSI-IV
	Raven's CPM	RAVEN
Receptive vocabulary	BPVS-II	BPVS-II

5.6 Measures of Morphological Awareness

The morphological awareness tasks have been constructed for the *NumLit* project and validated in Norwegian by García Grande (2018); they were developed following the paradigm of the morphological awareness tasks in Greek developed by Diamanti et al. (2018). One task taps the awareness of inflectional morphology and the other the awareness of derivational morphology.

5.6.1 Meta-inflectional Awareness Production Task

For the administration of the Meta-inflectional task, the children were shown a pair of images that depicted turtles conducting various actions. The images were provided alongside an orally presented sentence. The children were explained that the examiner would say certain words in the special language that the turtles use. Thereafter, the child was presented with the beginning of a second sentence that matched the paired image, and was asked to respond with the ending of the sentence which included a targeted pseudo-word. The pseudo-words were invented words that bared no semantical meaning, but were created to resemble the syllabic and orthographic structure of other Norwegian words (García Grande, 2018). Specifically, the child was asked to grammatically inflect the pseudo-words by the change of word number (i.e. from singular to plural or from plural to singular, accordingly). For example, the child was presented with an image of a turtle playing with one cat alongside an image of a turtle playing with three cats. The sentences corresponding to the images were "The turtle plays with a cat*"* and "The turtle plays with three…" ("Skilpadden leker med en duss", "Skilpadden leker med tre… " in Norwegian), with *cats* (*dusser* as the Norwegian pseudo-word) in plural form as the correct response. There were a total of 16 items; six pseudo-verbs, five pseudo-adjectives, and five pseudo-nouns. The children were provided four practice items comprising two pseudo-verbs, one pseudo-noun, and one pseudo-adjective. If the children used the familiar word instead of the pseudo-word, they were encouraged to remember to use the same language as the turtles. For the scoring of the test, one point was given for correctly produced inflections. The children were also awarded if the word was inflected grammatically correct but not in the expected form; for instance, if the child was presented with a sentence in definite form but completed it in indefinite form (e.g. responded with "to *kebler*" instead of "*keblene"* in Norwegian).

5.6.2 Meta-derivational Awareness Production Task

In the Meta-derivational Task the children were initially shown an image, while being presented orally with a sentence including a target word to match the image. Subsequently, the beginning of a second sentence was introduced, and the children were asked to provide the final word of the sentence. The paired sentence was a syntactically altered version of the first sentence, which in turn necessitated a derivation of the targeted word. For most of the items the target word in the first sentence was a stem morpheme, while the second sentence required the child to derive the stem morpheme, for example "The cat has a lot of hair" paired by "The cat is very… [hairy]" ("Katten har mye hår", "Katten er veldig…[hårete]"). The stem morphemes in this task were either nouns, adjectives, or verbs, and most of the tasks expected the child to change the word class by attaching the appropriate suffix. Two items were decomposition tasks, in which the child was expected to provide the stem morpheme as the target word, by removing the suffix from the derived morpheme in the preceding sentence. For example, in the sentences “The boy loves reading” and “The boy likes to…” (“Gutten er glad i lesing”, “Gutten liker å…”), the stem morpheme “read” (“lese”) was the correct reply. There were a total of 14 items in the task. Four practice items were introduced in advance of the task. The examiner stressed the target word in the first sentence of the practice items. For the scoring of the task, one point was given for correct derivations and zero points for incorrect answers.

5.7 Measures of Working Memory

Working memory was measured by Listening Recall and Backward Digit Recall, in which both are subtests taken from the test battery *Working Memory Test Battery for Children* (WMTB-C) (Pickering & Gathercole, 2001). WMTB-C is a standardised test developed for children within the age range 5;0-15;0. The test battery is based on the working memory model by Baddeley and Hitch (1974) (Pickering & Gathercole, 2004). Listening Recall and Backward Digit Recall are both measures of the central executive component, and a common feature of the subtests is that they both provide the participants with verbal content that must be temporarily stored and processed (Pickering & Gathercole, 2001).

5.7.1 Backward Digit Recall

The children were presented a string of digits and encouraged to repeat the sequence of digits in the reversed order. Thus, when the examiner introduced the numbers “9, 4”, the required reply was “4, 9”. For this task the child was expected to hold the span of digits in their memory for the certain amount of time it took to transform the memory before replying. The children were initially provided with two practice items that had a span of two digits. The test administrator thereafter proceeded to present the two digit test items. The test had an incline in difficulty; the amount of digits increased with one digit per block. Each block consisted of six items and there were six blocks in total. If the child answered correctly for the four first items in the block, the next block was administered, and the child received points for all items within the block. The child reached the stopping criterion when there were three errors within the same block. Scores were noted as correct when the child managed to recall all the digits of the item in the accepted reversed order. The maximum span of digits the child recalled was also noted.

5.7.2 Listening Recall

Listening Recall is a two-folded task. Firstly, it demands a semantic judgment of a series of spoken sentences, where the child is expected to listen to a sentence and afterwards judge its veracity by responding true or false (sann/usann in Norwegian). Secondly, the child is to recall the final word of the spoken sentence. For the administration, the child was presented with a sentence and asked to judge the sentence as true or false, and afterwards repeat the last word of the sentence. For instance, when the child was presented with the sentence “lions have four legs” (“løver har fire ben”), the required response was “true, legs” (“sann, ben”). After the two first blocks the test had an increase of one sentence per block. For multiple sentences, the child was instructed to answer true or false after each sentence presentation, and thereafter recall the final word of each sentence in chronological order after the last sentence of the item had been administered. The test had six blocks with six items in each block. All sentences were matched in length and difficulty. The next block was administered if the child responded correctly to the four first items, and points were given for all the items within the block. The stopping criterion was three errors within the same block. Two practice items were administered prior to the first block with one sentence-items, and two practice items were given prior to the second block with two sentence-items. Due to the complexity of the task instructions, the task was terminated if the child did not reach the correct response after the examples were administered three times. The scoring of the test was not affected by whether the child correctly judged the veracity of the sentences, but points were given based on whether the last words were correctly recalled.

5.8 Measure of Receptive Vocabulary

5.8.1 British Picture Vocabulary Scale II

Receptive vocabulary was assessed with the Norwegian version of *The British Picture Vocabulary Scale, Second Edition* (BPVS-II) (Dunn & Dunn, 2009; Lyster, Horn, & Rygvold, 2010). The Norwegian version was translated and normed to match Norwegian conditions, and is based on the results from 884 children (Lyster et al., 2010). The test is targeted at children within the age group 3;0-16;1, and is a measure of vocabulary breadth. The test has been digitalised especially for *NumLit,* hence the data in this study comes from the computerised version. For each item the participant children were presented with four images on a computer screen, while a recorded spoken word was played concurrently. The child was then asked to point to the image that corresponded to the audio clip. There was an incline in difficulty; the test begun with high frequent and concrete words, and progressed to more infrequent and abstract words. There were 12 blocks containing 12 items each. The stopping criterion was reached when there were eight or more errors within the same block. The test was scored automatically.

5.9 Measures of Nonverbal-IQ

5.9.1 Matrix Reasoning

Matrix Reasoning is a subtest from *Wechsler Preschool And Primary Scale Of Intelligence – Fourth Edition* (WPPSI-IV), which is a standardised intellectual ability test for children within the age range 2;6-7;7 (Wechsler, 2012). The present study used a computerised version of Matrix Reasoning. For this task the participant was requested to analyse a whole into its component parts; the child was presented with an incomplete matrix on the computer screen, and was requested to point out the missing piece to logically fit the matrix. There were 26 items, with three practice items that were introduced at the beginning of the test. Each block increased in difficulty. The stopping criterion was three consecutive scores of zero, and the scoring was completed automatically.

5.9.2 Raven's Coloured Progressive Matrices

Nonverbal-IQ was additionally measured by Raven's Coloured Progressive Matrices (Raven's CPM) (Raven, 2004), which is a standardised test intended for children within the age range 4;0-11;0. A computerised version of the test made especially for *NumLit* was used. The children were shown an image on the computer screen of a pattern that had a piece missing. Subsequently, the children had to complete the pattern by pointing to the piece they believed to fit the pattern. Each item had six pieces to choose from. Two practice items were administered, and there were a total of 34 items excluding the practice items. The items were hierarchically organised, in the sense that the task started with the easiest items and advanced in difficulty. There was no stopping criterion, and the scoring was performed automatically.

5.10 Validity

Cook and Campbell (1979) have classified validity into four subcategories to be applied for causal research. This classification is also relevant for descriptive research (Kleven, 2002b), and will therefore guide the understanding of validity in this study.

5.10.1 Statistical Validity

Statistical validity refers to the extent in which it is possible to make general assumptions about the effects found between the variables of interest. The assumptions made are based on whether or not the results are found to be statistically significant; if the found effect is strong and statistically significant, it is reasonable to assume high statistical validity (Lund, 2002). However, in research there is always a risk of drawing incorrect conclusions; this risk especially pertains to a small sample size, or to sampling error (Cook & Campbell, 1979). In statistical analysis error is divided into two type errors, known as Type-I and Type-II errors. These type errors are intrinsically connected to the null-hypothesis, which is the hypothesis that there is no found effect or correlation. The rejection of the null hypothesis when the null hypothesis in fact is correct is termed a Type-I error, while the decision to keep the null hypothesis when it should be rejected is referred to as a Type-II error (Gall et al., 2003). The probability of making a Type-I error is bound to the specified significance level. If the significance level is .05, it means that effect sizes with a corresponding p-value of .05 or less are found significant, and the probability of making a Type-I error is 5%. If the significance level is lowered, the risk of making a Type-I error is reduced at the expense of increased probability of making a Type-II error (Cumming & Calin-Jageman, 2017).

Unless stated otherwise, the desired significance level in the analyses within the present study is .05 or less. This means that effect sizes with a corresponding significance of $p > .05$ is found inseparable from the null-hypothesis, thus cannot be ascribed a significant effect. Moreover, the validity of null-hypothesis tests often require that statistical assumptions have been met for the results to be meaningful and interpretable (Cook & Campbell, 1979). This is important for the statistical analyses employed in this study, as multiple regression is based on specific assumptions that should not be violated. The assumptions of regression will be further outlined in the Results Chapter.

Finally, statistical validity further depends upon the reliability of the measures that have been employed (Cook & Campbell, 1979). Specifically, reliability refers to the extent to which data are free of measurement errors, and moreover how consistently the test measures what it is assumed to measure (Kleven, 2002a), thus, the reliability of the test also provides a foundation for the overall construct validity (Lund, 2002). Reliability can be determined through test-retest estimates; if the test is reliable it entails that the score of a specific participant correlates with the score that the same participant achieves in repeated testing, provided that the person has not changed nor developed (R. J. Cohen & Swerdlik, 2018). Reliability further concerns the internal consistency of a test, which is an indication of how consistently the items within a test measure the same construct (Gall et al., 2003). Reliability is often established through statistical tools that estimate correlation between and within tests. The internal consistency reliability of each test used in this study will be reported in the Results Chapter, and is provided by the Cronbach's alpha coefficient and the Revelle's omega total coefficient.

5.10.2 Internal Validity

Internal validity regards the inferences that have been made about the associations and causality between the variables of interest (Cook & Campbell, 1979). If it has been found that the variables correlate, internal validity relates to the degree it is possible to ascertain the direction of this relationship (Cook & Campbell, 1979). As this study has a non-experimental design, it is not possible to draw firm conclusions on the causality and direction of the relationship between the variables. However, hierarchical multiple regression analysis is utilised in this study to improve the internal validity, as it can provide some information on the prediction made by one variable upon another, while controlling for possible confounding variables (Kleven, 2002b). Some relevant threats to internal validity within this study could relate to testing, meaning that the repetition of being exposed to the same test across multiple timepoints could affect the test scores, as well as instrumentation, meaning that there could be measurement error related to an aspect of the measurement instrument (i.e. test) (Cook & Campbell, 1979).

5.10.3 Construct Validity

Construct validity engages with how well the theoretical constructs of interest have been operationalised and measured (R. J. Cohen & Swerdlik, 2018). This study has chosen to rely on tests to measure the constructs of interest. However, tests can only be considered valid insofar as they are measuring the ability or trait they have been employed to measure (R. P.

McDonald, 2011). Psychometric tests used in the field of education often measure hypothesised latent constructs that are not directly observable, such as skills, personality traits, and intelligence (R. P. McDonald, 2011). Furthermore, these constructs might not be distinguishable entities, in the sense that they could be confounded by other constructs (Cook & Campbell, 1979). It is therefore of importance to assess if the tests actually measure the latent traits they have been designed to measure. Evidence for the construct validity of a test can be established by examining whether the test scores correlate with the scores of other tests that have been employed to measure the same construct. Additionally, if the test scores resemble pre-existing theory about the construct, this can be a further indication that conditions of construct validity has been met (R. J. Cohen & Swerdlik, 2018).

5.10.4 External Validity

External validity relates to the degree it is possible to infer that the obtained result in the sample is generalisable to its related population, as well as how generalisable this result is across different persons, time, and situations (Cook & Campbell, 1979). The representativeness of a sample can be determined by the sample size, the sampling process, and the homogeneity within the sample (Lund, 2002). A threat to the validity in this study is that the study relies on a convenience sample, meaning that the validity is not as strong as in studies that have included a randomised sample (Cook & Campbell, 1979). Notably, the present study wishes to make generalisations about the interrelationship of cognitive and linguistic development in typically developing children with Norwegian as their first language, making reflections pertaining to external validity important.

5.11 Ethical Considerations

This study is conducted in association with the research project *NumLit.* This project has been approved by *Norwegian Centre for Research Data* (NSD). The present study relies on data obtained from the testing of children, and should therefore make particular considerations to ensure the protection of the children involved (NESH, 2016). Formal requirements have been met in accordance with the *Guidelines for Research Ethics* (NESH, 2016). In detail, parental consent for all of the participants was collected at the start of the project, as well as oral assents from the participant children. The parents were provided information about the project, and were also informed that participation was voluntary and that they were free to withdraw from the project at any point. Furthermore, the participants were informed that the data collected would be treated confidentially, and anonymised as well as deleted at the end of the project. The research assistants undertook obligatory training, and it was additionally assured that the research assistants had knowledge of children and testing by recruiting them from relevant departments of the university. All the test sessions were audio recorded, which functioned as an assurance for the participants and the research group.

6. Results

6.1 Descriptive Statistics of the Variables

The sample in this study comprises 216 cases. As in most longitudinal studies there were some missing data, and 20 of the cases had missing values. Due to the data missing being only a few cases of a random pattern they were discarded by being filtered out of the sample (Tabachnick & Fidell, 2014). Furthermore, one outlier of a score of zero (in BPVS-II) was trimmed and removed as it appeared to be nonrepresentative of the other scores, thus likely to have occurred by error during test administration or by incorrect data entry. The final sample used for analyses is therefore a total of 195 cases.

Prior to the multiple regression analyses, descriptive statistics of each variable will be presented. A summary of the descriptive statistics and reliabilities for the predictor and outcome variables are reported in Table 2. Descriptive analysis provides an overview of the relevant variables and their distribution. Skewness and kurtosis are valuable measures for determining the normality of a given distribution. Skewness provides information on the symmetry of the distribution, in which skewness with a value of zero reflects a distribution of perfect symmetry (Field, 2018). A positively skewed distribution has high levels of low scores, and an extended right tail, while a negatively skewed distribution has an extended left tail with an overweight of high values (Field, 2018). The kurtosis reveals information about the peak of the distribution; positive kurtosis values show a tendency of an overweight of values in the tails, while a negative kurtosis value signals few values in the tails (R. J. Cohen & Swerdlik, 2018). The further the values of skew and kurtosis deviate from zero, the more the distribution deviates from normality (Field, 2018).

Internal consistency reliability of the tests is measured with Cronbach's alpha (α) and Revelle's omega total (ω_t). Both Cronbach's alpha and Revelle's omega provide coefficients of inter-item correlations (R. J. Cohen & Swerdlik, 2018). It is optimal to obtain a strong correlation within tests where items are tapping the same constructs, as is the case with the tests used in this study. Internal consistency reliability is considered achieved for both Cronbach's alpha and Revelle's omega when values are .7 or more (Louis Cohen, Manion, & Morrison, 2018).

Multiple regression requires there to be a single outcome variable. In accordance with this, the subscale measures of morphological awareness (i.e. meta-inflectional and meta-derivational tasks) were transformed to one composite variable for pre-school, one composite variable for Grade 1, and one composite variable for Grade 2. Based on the intercorrelations amongst the tasks at each grade level (see Table 3; r_s= .466 for pre-school, r_s= .402 for Grade 1, and r_s= .369 for Grade 2), and on the fact that the tasks were designed and validated to tap the same overarching construct that is morphological awareness (see García Grande, 2018), this seems justifiable. Both the subscale measures and the composite measures will be reported in advance of the main analyses, whereas only the composite measures will be reported and used for the regression analyses.

Age was initially run in the analyses as a predictor variable, however, it showed no significant correlations with any of the predictor or outcome variables (all p >.05, except Listening Recall with p >.01). This variable was therefore excluded from the analyses, and will not be considered further.

Table 2. *Descriptive Statistics of All Variables*

Variable	*N*	*M*	*Mdn*	*SD*	*Range*	*Skewness*	*Kurtosis*	*α*	ω_t
Pre-school Predictor Variables									
Backward Digit Recall	195	5.76	6	3.59	0-14	−.10	−.63	.85	.88
Listening Recall	195	4.47	1	5.41	0-21	.83	−.61	.93	.95
Matrix Reasoning	195	11.40	11	5.24	1-22	.06	−1.07	.86	.87
Raven's CPM	195	17.76	18	4.40	7-35	.25	.60	.73	.73
BPVS-II	195	64.03	63	11.95	37-91	.13	−.82	.90	.92
Meta-inflectional Task	195	7.19	7	4.01	0-16	.17	−.70	.84	.84
Meta-derivational Task	195	4.73	5	2.24	1-11	.54	.18	.65	.66
Morphological Awareness	195	5.96	6	2.71	0.5-12.5	.20	−.56	.85	.84
Grade 1 Outcome Variable									
Meta-inflectional Task	195	10.12	11	4.54	0-16	−.80	−.35	.87	.88
Meta-derivational Task	195	5.68	6	2.30	0-12	.08	.27	.61	.62
Morphological Awareness	195	7.90	8.5	2.94	0-13	−.62	−.42	.86	.85
Grade 2 Outcome Variable									
Meta-inflectional Task	195	9.91	11	3.93	0-16	−.56	−.60	.83	.84
Meta-derivational Task	195	7.18	7	2.40	1-13	−.26	−.32	.65	.65
Morphological Awareness	195	8.54	9	2.68	1.5-14	−.52	−.27	.85	.84

N= Number of participants; M= mean; mdn = median; SD = standard deviation; range is from lowest to highest observed value; α = Cronbach's alpha; ω_t *= Revelle's omega total*

6.1.1 Backward Digit Recall (Pre-school)

The distribution of the Backward Digit Recall test has two distinct peaks, where the peak in the left tail is due to a large amount of a score of 0, and the highest peak a score of 6. The kurtosis deviates negatively with a value of -.63, which reflects that the distribution generally has fewer datapoints in the tails than the expected normal distribution. The skewness is -.10, and indicates that the distribution is close to being symmetrical. The mean is 5.76 and the median is 6. The test has an internal consistency of $\alpha = .85$, and $\omega_t = .88$.

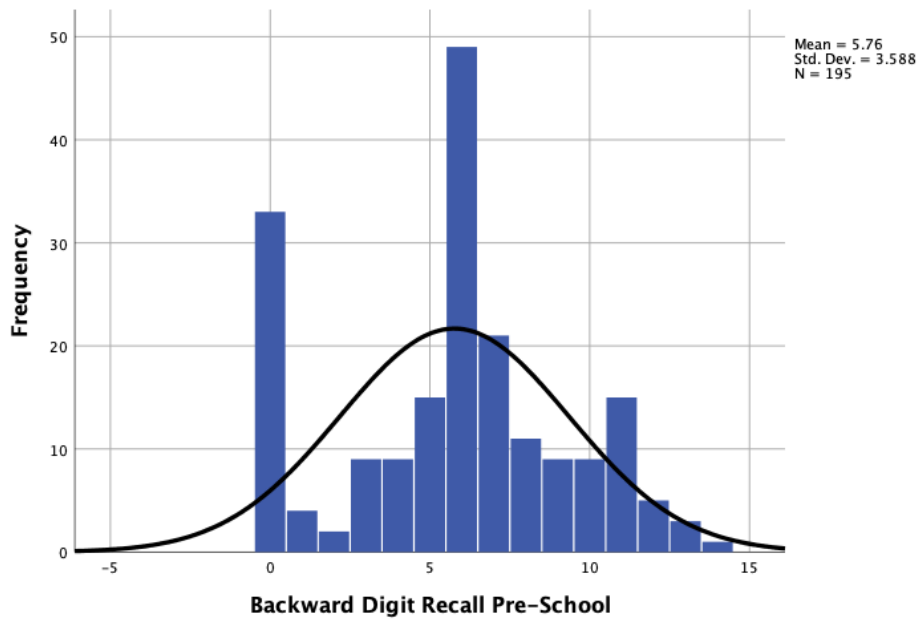

Figure 2. *Histogram of Backward Digit Recall from Pre-school*

6.1.2 Listening Recall (Pre-school)

The histogram shows a distribution that diverges strongly from the normal distribution. There is one clear peak in the left tail, and the kurtosis is -.61. A substantial proportion of the values (87 of 195) are a score of 0, which creates a floor effect. This implies that almost half of the children at pre-school level did not master this test. The skewness is .83, and is indicative of a distribution that is asymmetrical. The mean is 4.47 and the median is 1, in which both values are pulled towards the left tail of the distribution due to the floor effect. Listening Recall has a strong internal consistency, with $\alpha = .93$, and $\omega_t = .95$.

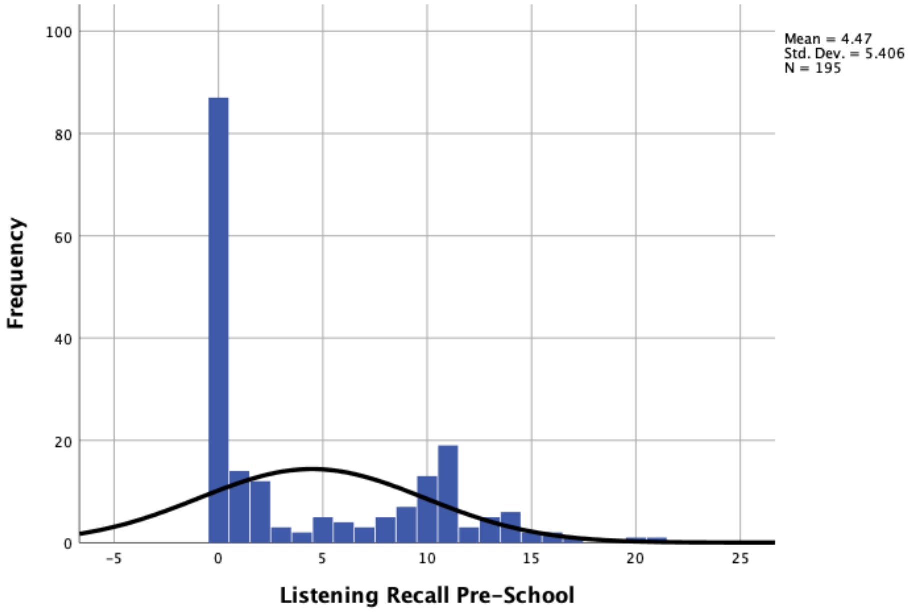

Figure 3. *Histogram of Listening Recall from Pre-school*

6.1.3 Matrix Reasoning (Pre-school)

The histogram shows a bimodal distribution with a kurtosis of -1.07. The mean of 11.40 and median of 11 are centred between the minimum achieved score of 1 and the maximum score of 22. However, a minority of the values are concentrated around the mean, which creates a trough (i.e. low point) in the middle of the distribution. The distribution is closely symmetrical with a skewness of .06. The reliability coefficients are $\alpha = .86$, and $\omega_t = .87$.

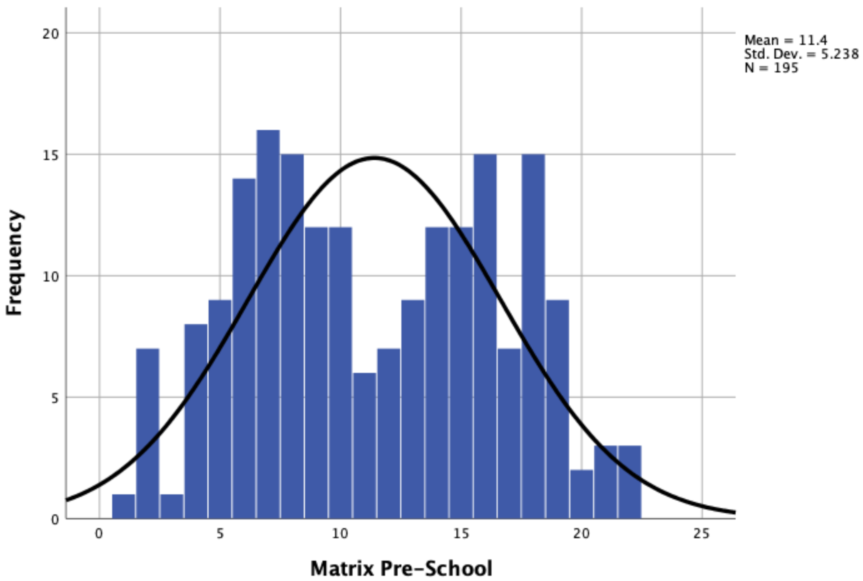

Figure 4. *Histogram of Matrix from Pre-school*

6.1.4 Raven's CPM (Pre-school)

The skewness of .25 and kurtosis of .60 both reflect a distribution that does not extensively deviate from normality. The mean is 17.76 and the median 18. The highest attained score of 35 seems to be an outlier in the distribution, and lies six points above the next highest score. The test has an internal consistency of $\alpha = .73$ and $\omega_t = .73$

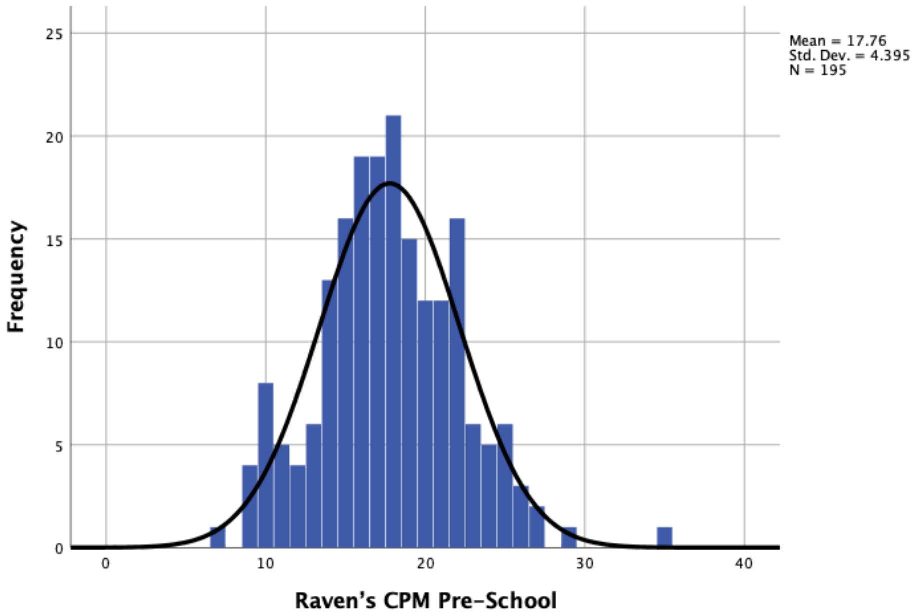

Figure 5. *Histogram of Raven's CPM from Pre-school*

6.1.5 BPVS-II (Pre-school)

The histogram shows that BPVS-II from pre-school has a distribution with a slight right skew of .13. The distribution has several peaks, and a kurtosis of -.82. The mean is 64.03 and the median is 63. There was initially one outlier with a score of zero in the left tail, and this score was excluded by being trimmed. The internal consistency of the test is strong, with $\alpha = .90$, and $\omega_t = .92$.

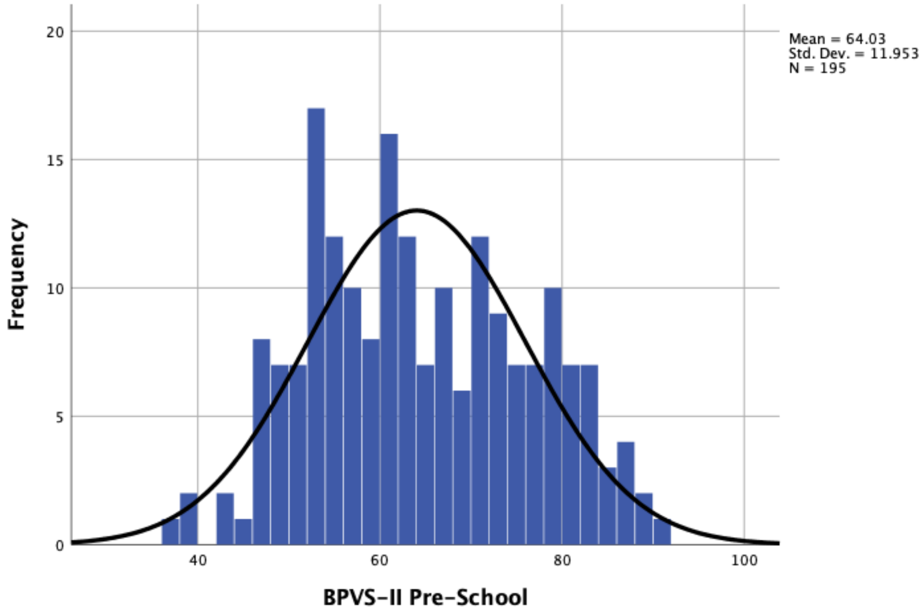

Figure 6. *Histogram BPVS-II from Pre-school*

6.1.6 Meta-inflectional Production Task (Pre-school)

The distribution of the Meta-inflectional task from kindergarten has a skewness of .17, and a kurtosis of -.70, which reflects that it is a slightly flat distribution with many high values in the tails. The mean of the distribution is 7.19, and the median is 7. The test has an internal consistency of $\alpha = .84$ and $\omega_t = .84$.

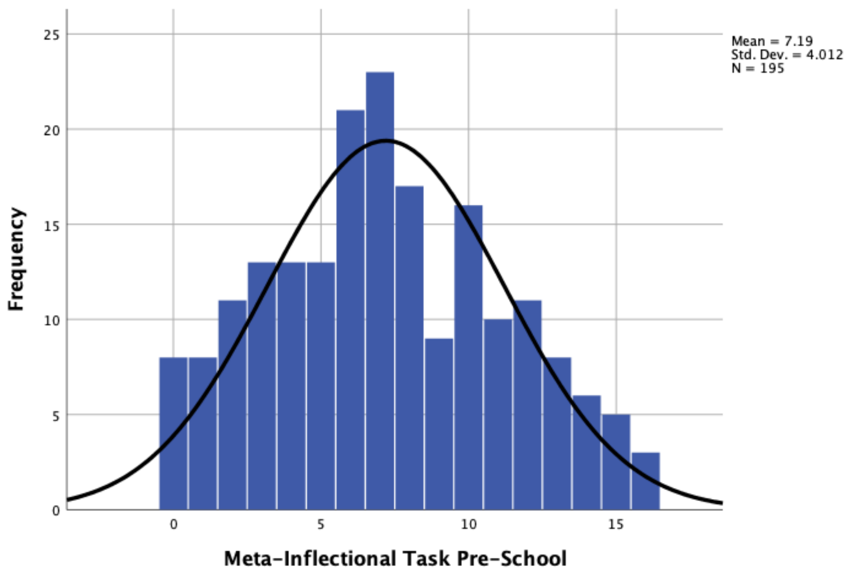

Figure 7. *Histogram of the Meta-inflectional Task from Pre-school*

6.1.7 Meta-derivational Production Task (Pre-school)

The histogram shows a tendency of high values in the left tail of the distribution, with a right skew of .54. This indicates that the meta-derivational task proved challenging for some of the participants at pre-school level. The distribution has a kurtosis of .18. The mean is 4.73 and the median is 5. The internal consistency coefficients yielded a relatively weak reliability, with $\alpha = .65$ and $\omega_t = .66$.

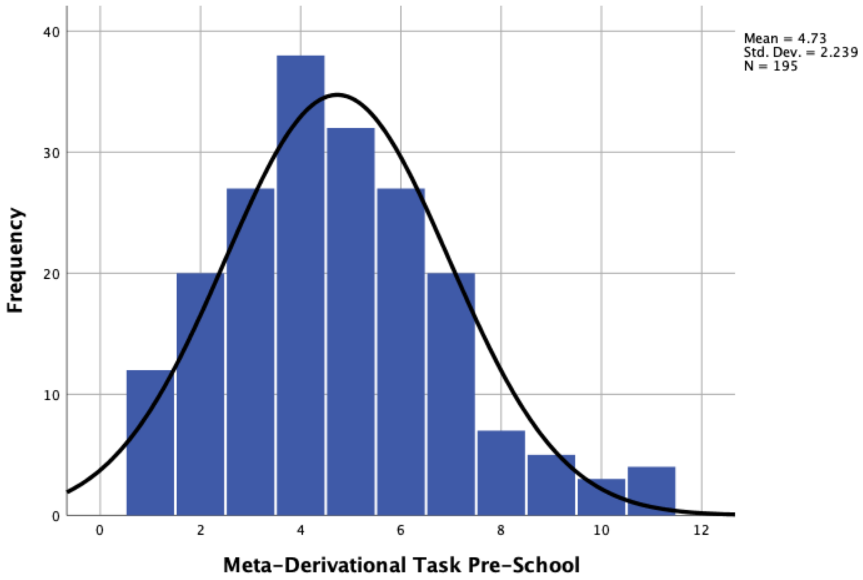

Figure 8. *Histogram of the Meta-derivational Task from Pre-school*

6.1.8 Morphological Awareness Composite (Pre-school)

The histogram shows a symmetrical distribution that is evenly dispersed, reflected by a skewness of .20. The kurtosis is -.56, and is due to centred values that provide few values in the tails. The mean is 5.96, and the median is 6. The internal consistency of the composite morphological awareness measure is $\alpha = .85$ and $\omega_t = .84$.

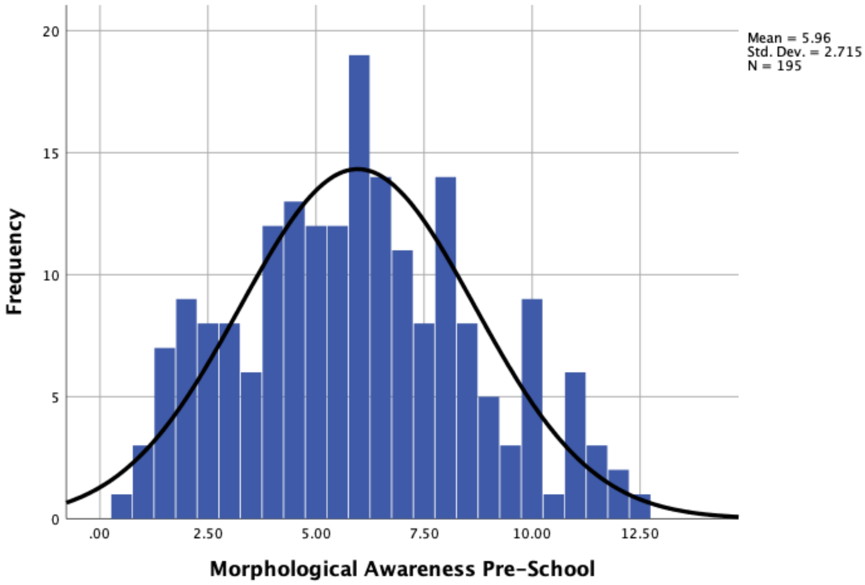

Figure 9. *Histogram of the Morphological Awareness Composite from Pre-school*

6.1.9 Meta-Inflectional Production Task (Grade 1)

The mean of the Meta-inflectional task from first grade is 10.12 and the median is 11. There is a negative skew of -.80. The asymmetrical distribution is due to a large proportion of high scores in the right tail, which indicates that the majority of the children performed well in the task. However, a ceiling effect has not yet been reached. The kurtosis is -.35, which reflects the peak towards the right tail of the distribution. The reliability coefficients of the task are $\alpha = .87$ and $\omega_t = .88$.

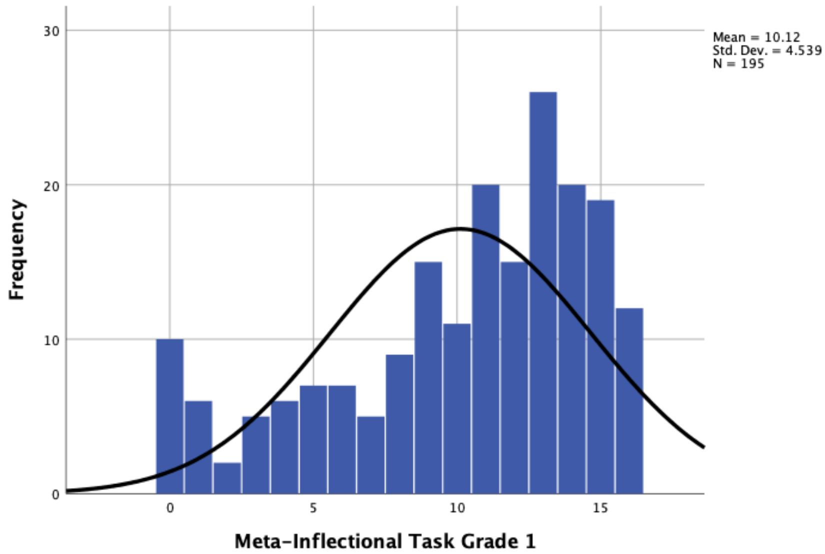

Figure 10. *Histogram of the Meta-inflectional Task from Grade 1*

6.1.10 Meta-Derivational Production Task (Grade 1)

The meta-derivational task from Grade 1 has a distribution with the majority of the values centred in the middle, and few values in the tails. The distribution has a mean of 5.68 and a median of 6. The skew of .08 and the kurtosis of .27 both indicate that the distribution is approximate to normality. The internal consistency of the meta-derivational task is $\alpha = .61$ and $\omega_t = .62$.

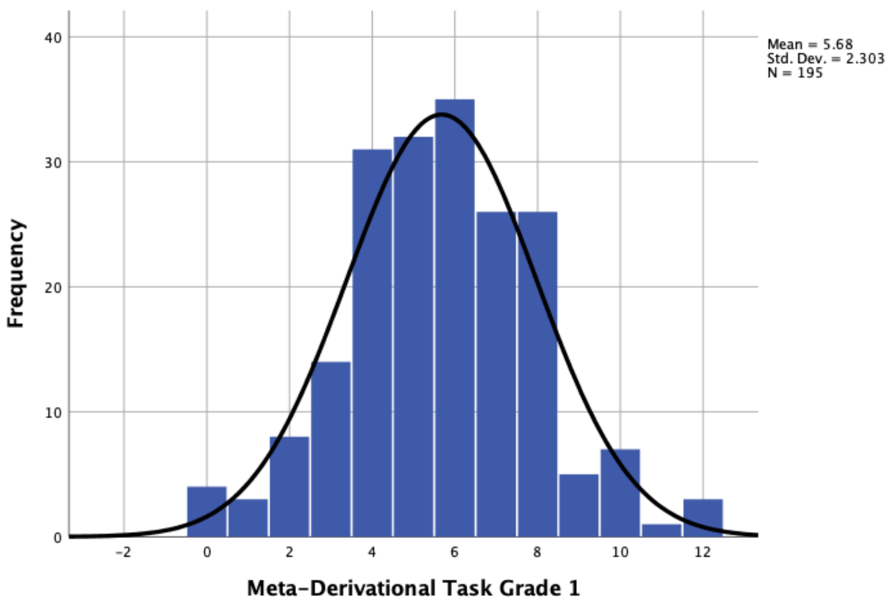

Figure 11. *Histogram of the Meta-derivational Task from Grade 1*

6.1.11 Morphological Awareness Composite (Grade 1)

The distribution has most of the values clustered towards the end of the right tail, with a negative skew of -.62. This indicates that the majority of the participants performed well in the morphological awareness tasks. The kurtosis is -.42, the mean 7.90, and the median 8.5. The morphological awareness composite from Grade 1 has an internal consistency reliability of $\alpha = .86$ and $\omega_t = .85$.

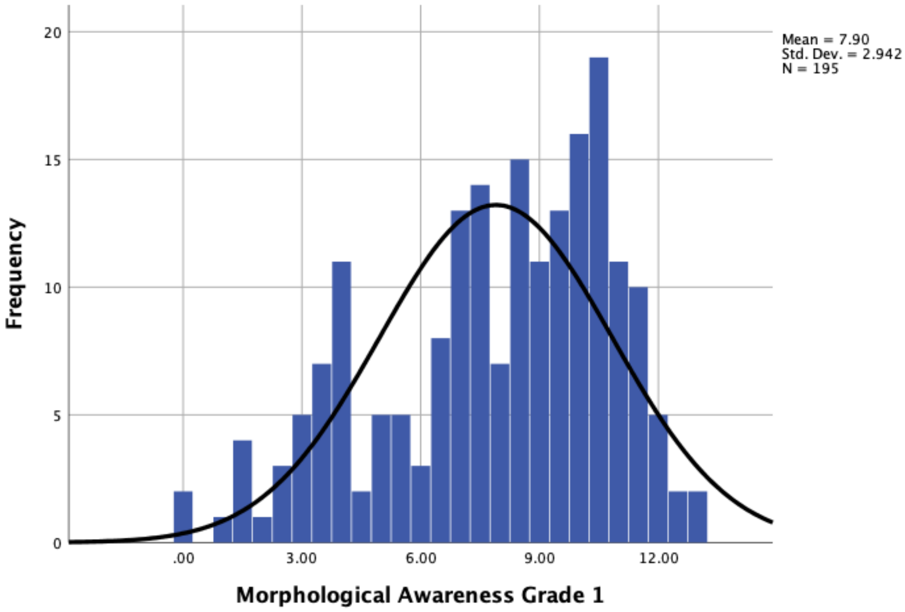

Figure 12. *Histogram of the Morphological Awareness Composite from Grade 1*

6.1.12 Meta-Inflectional Production Task (Grade 2)

The histogram shows a left skewed distribution with a skewness of -.56, and a kurtosis of -.60. As can be recognised by the histogram the scores are clustered towards the right tale, which shows that most of the children mastered the task. The mean is 9.91 and the median 11, which shows improved scores from the mean of 7.19 and median of 7 attained in the Meta-inflectional task at pre-school level. The reliability coefficients are $\alpha = .83$ and $\omega_t = .84$.

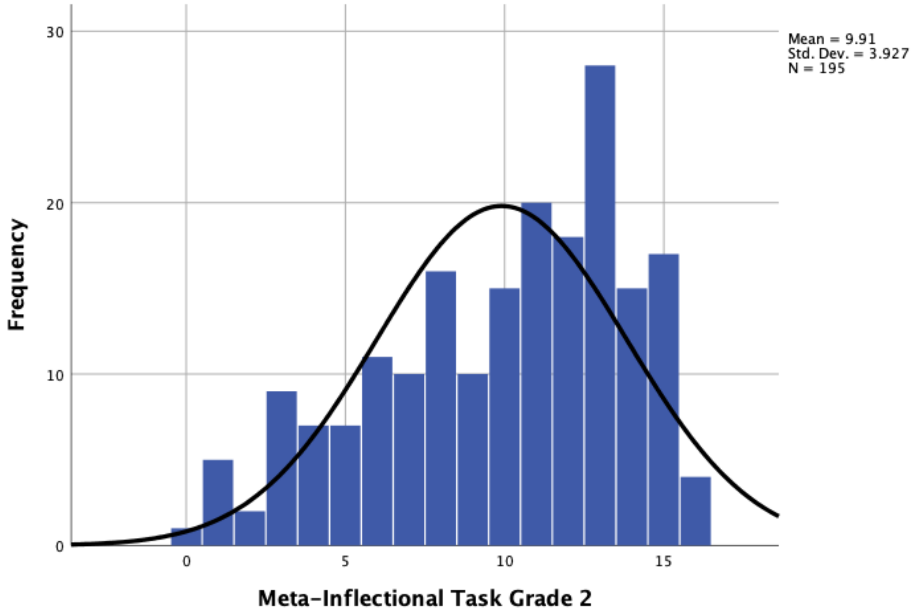

Figure 13. *Histogram of the Meta-inflectional Task from Grade 2*

6.1.13 Meta-Derivational Production Task (Grade 2)

The meta-derivational task from Grade 2 has a slightly left skewed peak with a negative skew of -.26 and negative kurtosis of -.32. The mean is 7.18 and median 7, and it can be seen from the histogram that the distribution does not deviate too extensively from normality. The internal consistency of the task is α = .65 and ω_t = .65.

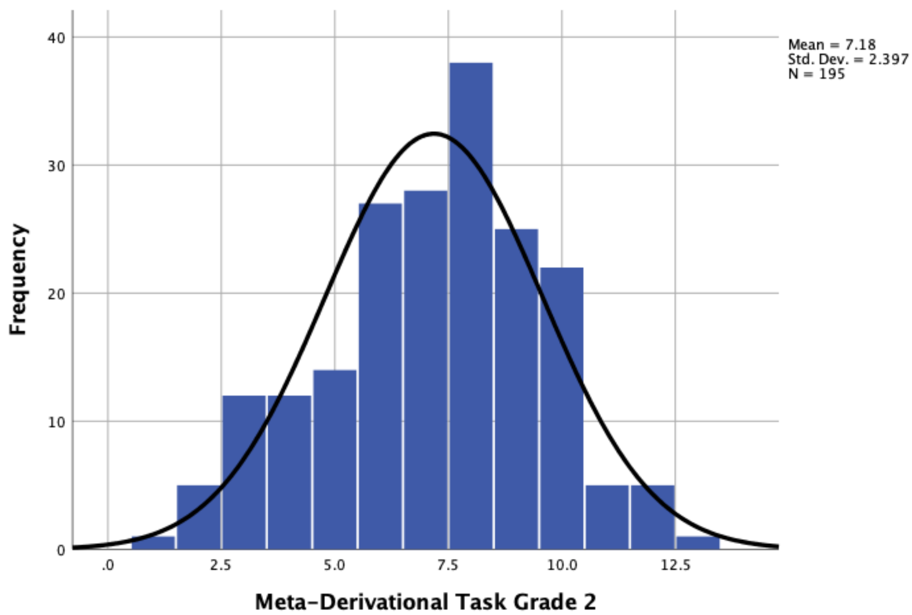

Figure 14. *Histogram of the Meta-derivational Task from Grade 2*

6.1.14 Morphological Awareness Composite (Grade 2)

The composite score of morphological awareness in Grade 2 is asymmetrical with an overweight of high values. Accordingly, there is a skewness of -.52, and kurtosis of -.27. The mean of 8.54 and median of 9 suggest a slight improvement in performance when compared to the Grade 1 morphological awareness measure that provided a mean of 7.90 and median of 8.5. The composite morphological awareness measure from Grade 2 has a reliability of α = .85 and ω_t = .84.

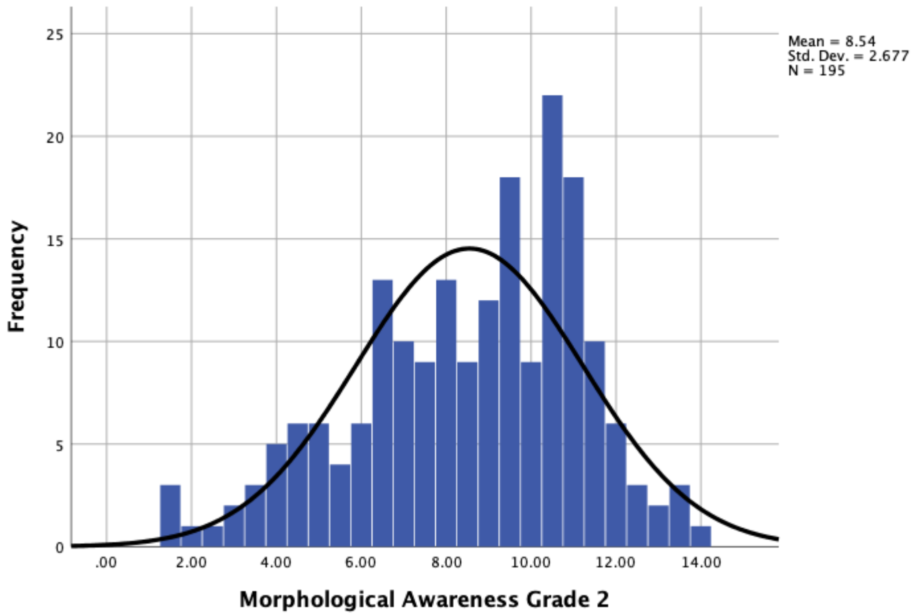

Figure 15. *Histogram of the Morphological Awareness Composite from Grade 2*

6.2 Bivariate Correlations

Prior to the multiple regression analyses, the strength of association between the predictor variables and both outcome measures (i.e. composite morphological awareness from Grade 1 and Grade 2) will be addressed. The bivariate correlations (displayed in Table 3 below) are estimates of the strength of association among two variables (Field, 2918). A correlation between variables indicates that the variables covary; a negative r value means that the increase of one variable is associated with the decrease in the other variable, while a positive r implies that the values increase or decrease co-ordinately (Field, 2018). Correlation is commonly estimated by the Pearson product-moment correlation coefficient (r), which takes on a value within the range of -1 and +1. An r of -1 or +1 suggests a perfect correlation, while an r of 0 indicates no association between the variables of interest (Tabachnick & Fidell, 2014). Pearson's r demands for variables to be normally distributed (Field, 2018). Due to the identification of some non-normal distributions as presented by the descriptive statistics, correlation coefficients are reported by both Pearson's r and Spearman's ρ (r_s) in Table 3 (only by Spearman's ρ in text). Spearman's ρ is a coefficient for non-parametric distributions, based on ranked data, and takes on the same range of values as r (±1) (Field, 2018). From the correlation coefficients a squared correlation can be estimated, denoted as r^2 for Person's r and as r_s^2 for Spearman's ρ. The squared correlation provides an estimate of the proportion of variance that is shared by the variables, and is reported in percentages (Tabachnick & Fidell, 2014).

The correlation matrix presented in Table 3 displays that the majority of the variables correlate significantly at $p < .01$, with some significant at $p < .05$, and a few nonsignificant. Firstly, the relationship between the working memory predictors and the composite morphological awareness outcomes are of most interest. It can be noticed that Backward Digit Recall correlated significantly with the composite morphological awareness measure from Grade 1, with $r_s = .245$, $p < .001$, and an accompanying variance of 6 %. Similarly, in Grade 2, achievements in the Backward Digit Span task significantly related to achievements in morphological awareness with a slightly higher correlation of $r_s = .320$, and $r_s^2 = 10,2\%$ ($p < .001$). A comparable strength of relationship can be identified between Listening Recall and the composite morphological awareness measures in Grade 1 and 2, with a variance of 4,5% ($r_s = .214$, $p = .003$) and approximately 14 % ($r_s = .369$, $p < .001$), respectively.

Secondly, for the predictors to be controlled for, it was unsurprisingly the autoregressor that provided the strongest correlation with the outcome measure at both grade levels, with a variance of approximately 30 % (r_s= .544, p < .001) between the composite morphological awareness variable from pre-school and morphological awareness from Grade 1. For morphological awareness from Grade 2, the relationship with the autoregressor proved similarly strong, with around 28% shared variance (r_s= .525, p < .001). Additionally, moderate associations between BPVS-II and morphological awareness in Grade 1 and 2 were revealed. This is in accordance with other empirical findings that suggest links between achievements in receptive vocabulary and morphological awareness. For the Grade 1 outcome, BPVS-II shared a variance of approximately 9% (r_s= .302, p < .001), while for the Grade 2 outcome there was a shared variance of approximately 11% (r_s= .329, p < .001). Overall weaker associations were obtained between the measures of nonverbal-IQ and morphological awareness. Raven's CPM and morphological awareness from Grade 1 shared a variance of 3% (r_s= .175, p = .015), and almost 9% for Grade 2 (r_s= .293, p < .001). Matrix, on the other hand, displayed no significant associations with the outcome measures, with r_s= .066, p = .326 for Grade 1, and r_s= .139, p = .053 for Grade 2.

As a final note, the intercorrelations amongst the working memory measures should be outlined, as the two measures of working memory are employed in the analyses with the intent of tapping the same latent construct. It was identified that Backward Digit Recall and Listening Recall correlated significantly with each other (p <.001). However, their shared variance proved relatively limited, with 10.6% (r_s= .326), and it can therefore not be assumed that both measures tap the same working memory traits.

Table 3. *Intercorrelations Amongst All Variables*

Variable	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Pre-School														
(1) Backward Digit Recall	—	.326**	.118	.314**	.241**	.443**	.265**	.435**	.258**	.144*	.245**	.274**	.308**	.320**
(2) Listening Recall	.398**	—	.230**	.208**	.197**	.295**	.128	.276**	.198**	.197**	.214**	.368**	.236**	.369**
(3) Matrix Reasoning	.129	.224**	—	.288**	.174*	.214**	.141*	.211**	.016	.153*	.066	.123	.093	.139
(4) Raven's CPM	.303**	.241**	.320**	—	.240**	.381**	.190**	.356**	.220**	.056	.175*	.298**	.135	.293**
(5) BPVS-II	.219**	.250**	.177*	.226**	—	.449**	.327**	.481**	.312**	.200**	.302**	.333**	.186**	.329**
(6) Meta- Inflectional Task	.399**	.376**	.242**	.368**	.447**	—	.466**	.937**	.508**	.319**	.507**	.492**	.310**	.496**
(7) Meta-Derivational Task	.247**	.136	.137	.175*	.336**	.466**	—	.733**	.358**	.376**	.422**	.323**	.337**	.394**
(8) Morph. Awareness	.396**	.334**	.235**	.344**	.469**	.931**	.757**	—	.522**	.380**	.544**	.494**	.365**	.525**
Grade 1														
(9) Meta-Inflectional Task	.227**	.242**	.018	.183*	.332**	.479**	.349**	.498**	—	.402**	.909**	.595**	.351**	.600**
(10) Meta-Derivational Task	.137	.182*	.161*	.053	.215**	.326**	.385**	.400**	.417**	—	.721**	.371**	.247**	.380**
(11) Morph. Awareness	.228**	.257**	.077	.162*	.340**	.497**	.419**	.540**	.935**	.713**	—	.593**	.366**	.602**
Grade 2														
(12) Meta-Inflectional Task	.279**	.375**	.140	.278**	.342**	.511**	.330**	.514**	.635**	.368**	.634**	—	.369**	.903**
(13) Meta-Derivational Task	.296**	.217**	.126	.132	.196**	.297**	.356**	.366**	.331**	.267**	.360**	.398**	—	.716**
(14) Morph. Awareness	.337**	.372**	.159*	.263**	.338**	.508**	.401**	.541**	.614**	.389**	.626**	.912**	.740**	—

**Correlation is significant at the 0.05 level (Two-tailed) ** Correlation is significant at the 0.01 level (Two-tailed). Bottom left of diagonal is reported by Pearson's r; top right in blue is reported by Spearman's ρ*

6.3 Hierarchical Multiple Regression Analyses

Hierarchical multiple regression analyses are employed in this study to determine the effects of working memory upon morphological awareness. This form of analysis allows for the exploration of the individual contributions of multiple predictor variables on an outcome variable, by a prioritised entry of predictors (Roever & Phakiti, 2018). The main analyses (section 6.4) will report the unique and overlapping variance accounted for in the outcome variable by each predictor variable (Tabachnick & Fidell, 2014). Conclusions can subsequently be made on the unique variance in Grade 1 and Grade 2 morphological awareness attributable to pre-school working memory, above and beyond the effect of the autoregressor, nonverbal-IQ, and receptive vocabulary.

Multiple regression has assumptions that should be accommodated for the results to be interpretable (Tabachnick & Fidell, 2014). In general it should be ensured that the predictor and outcome variables are interval scaled. This assumption has been met. Furthermore, there should be no perfect multicollinearity; in other words, none of the predictor variables should correlate too highly (Field, 2018). As can be interpreted by the correlation matrix (Table 3), none of the predictor variables to be entered in the same regression analysis (thus, subscale measures of morphological awareness excluded) correlate to a higher degree than $r_s = .481$ (i.e. pre-school BPVS-II and pre-school morphological awareness). This assumption can therefore also be considered met. The remaining assumptions pertain to the distribution of the residuals; these assumptions were examined by residual diagnostics for each analysis as preliminary statistics to the regression analyses, and are presented in the following sections. Moreover, quantile-quantile plots (Q-Q-plots) and partial regression plots for each predictor variable (see appendix) were compared to the residual plots in order to more comprehensively ascertain if required assumptions were met.

6.3.1 Residual Diagnostics for the Prediction of Morphological Awareness Grade 1

The residual is an estimate of error of prediction, in which the distance between the predicted and the obtained value is calculated (Tabachnick & Fidell, 2014). Multiple regression analysis assumes that these residuals are normally distributed. By studying the scatterplot of standardised residuals (Figure 15) it can be noticed that the residuals are close to being evenly dispersed above and below the midline of zero, however, the values seem to cluster more above the line, and the amount of values decrease towards the right side of the plot. This is an indication that the residuals are close to being normally distributed, but that there is a slight deviation. This can further be recognised by the Q-Q-plot (Figure 16) which shows that most of the quantile residuals cling to the diagonal, apart from some values at both ends. There should additionally be a linear relationship between the predicted (dependent) variable and the errors of prediction. The scatterplot of residuals, as well as the partial regression plots, reveal no violations of linearity as the shape of the plots are close to being rectangularly dispersed without curvilinear traits (Tabachnick & Fidell, 2014). Furthermore, multiple regression relies on the distribution of residuals to be homoscedastic, in which the standard deviations of the residuals to some extent are equal for all the predicted scores. A perfectly homoscedastic distribution would therefore imply that all values around the regression line had a constant variance (Tabachnick & Fidell, 2014). The scatterplot of the residuals provides indications of an unequal scatter, suggesting a distribution that diverges slightly from the assumption of homoscedasticity. However, by closer examinations of the partial regression plots for each predictor variable, no heteroscedastic distributions were identified, and the assumption of homoscedasticity was therefore considered met.

Moreover, there should be an independence of errors, which entails that the residuals are uncorrelated. This assumption is commonly tested by The Durbin-Watson test, which provides values within the range 1-4 in which 2 means no autocorrelation between the errors (Field, 2018). The Durbin-Watson value of 1.95 obtained in this analysis indicates that the assumption of independence of errors has been met. A final assumption is the absence of multivariate outliers, identified as those residuals of large or small values that appear outside of the cluster in the scatterplot. By looking at the plot there seems to be one outlier outside of –3 standard deviations. To further investigate outliers in the data, Malahanobis distances was used, which indicates if the cases outside of the scatter belong to the population of interest. The Malahanobis distances are reported as chi-squares (χ^2), and have degrees of freedom equal to number of predictors. Critical χ^2 was found through the desired significance-level of .001 (table in Tabachnick & Fidell, 2014). From this, no significant outliers of extreme values were detected (highest value χ^2= 17.6, *df* 6, $p > .001$).

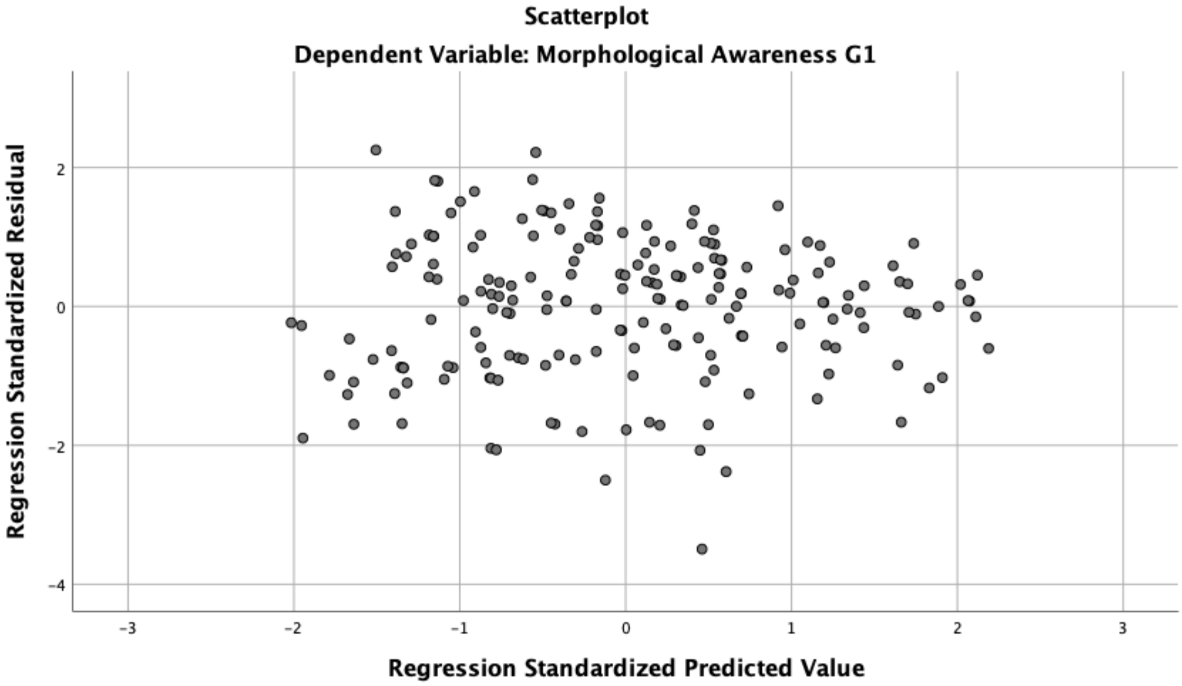

Figure 16. *Scatterplot of Standardised Residuals for the Prediction of Morphological Awareness Grade 1*

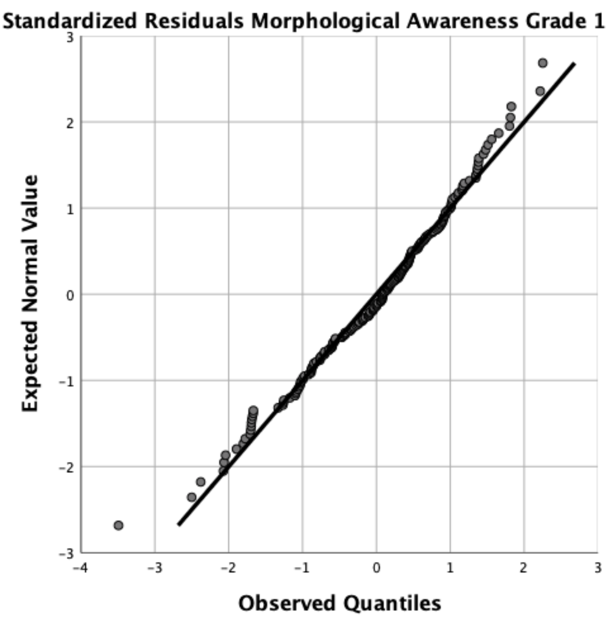

Figure 17. *Quantile-Quantile Plot of Standardised Residuals for the Prediction of Morphological Awareness Grade 1*

6.3.2 Residual Diagnostics for the Prediction of Morphological Awareness Grade 2

By examining the Q-Q-plot (Figure 18) and the scatterplot (Figure 17), the residuals appear to be close to normally distributed. The Q-Q-plot shows that the majority of the quantile residuals cling to the diagonal, and the scatterplot shows a rectangular and close to even scatter of the residuals, which accordingly suggests that the assumptions of linearity and homoscedasticity are met. The Durbin-Watson value of 2.13 implies that there is no autocorrelation, hence the assumption of independence of errors has been met. No extreme multivariate outliers were detected by Malahanobis distance (highest value $\chi^2 = 17.6$, *df* 6, $p > .001$).

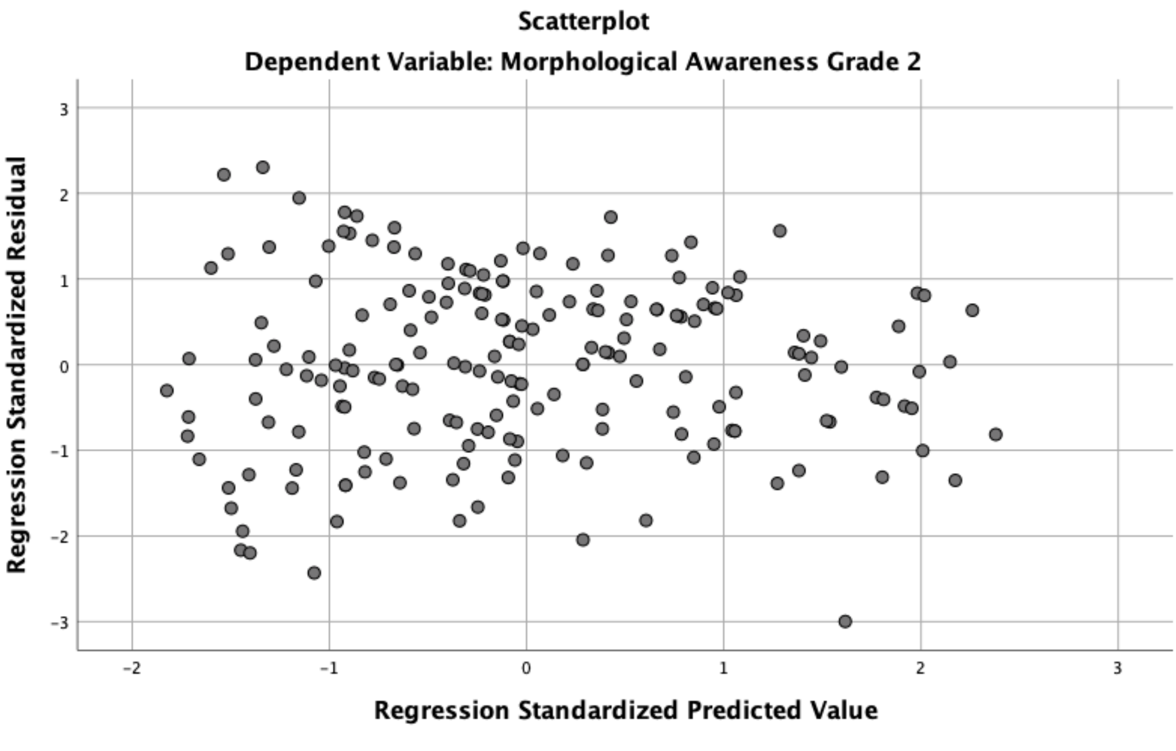

Figure 18. *Scatterplot of Standardised Residuals for the Prediction of Morphological Awareness Grade 2*

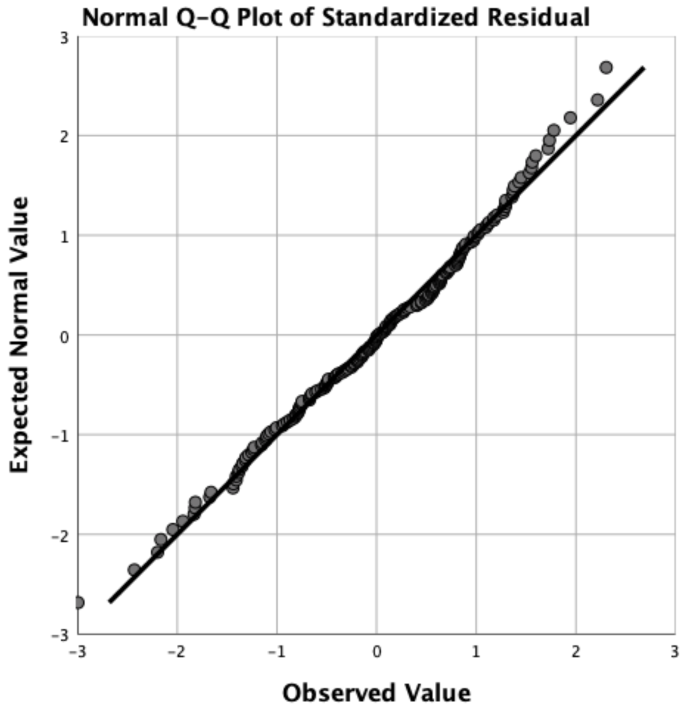

Figure 19. *Quantile-Quantile Plot of Standardised Residuals for the Prediction of Morphological Awareness Grade 2*

6.4 Results from the Regression Analyses

Hierarchical multiple regression analyses were performed, with morphological awareness in Grade 1 and 2 as outcome variables, and working memory as the predictor variable, while controlling for the effects of receptive vocabulary, nonverbal-IQ, and achievements of morphological awareness from pre-school. A hierarchical regression analysis of four steps was run for each outcome measure: in the first step the autoregressor was entered; in the second step the measure of receptive vocabulary was entered; in the third step the measures of nonverbal-IQ were entered; while in the fourth step measures of working memory were entered. The sequence of the predictors was based on their presumed relationship to the outcome; as it can be assumed that verbal abilities - here measured by prior morphological awareness and receptive vocabulary - are influential to later morphological awareness, they were prioritised entry. Considering the predominantly weak correlations between nonverbal-

IQ and morphological awareness, nonverbal-IQ measures were entered subsequently. Working memory was entered as the final step in order to reveal its specific contribution to morphological awareness, beyond the effects of the other predictors.

Table 4 displays the multiple correlation (*R*), the squared multiple correlations (R^2; total variance of the step), adjusted *R*, *R* square change (ΔR^2; improvement in variance when the step is entered), as well as the F change (F-test of R square change) and its corresponding *p*-value. Table 5 provides an overview of the obtained regression coefficients, reported as unstandardised *B* and standardised *β*, t-scores, the semipartial squared correlations (Sr^2; the unique variance offered to the total variance by each predictor when entered in the model), as well as associated *p*-values.

Table 6 and 7 of the ANOVA-statistics (see appendix) shows that the R^2 of each step was statistically significant with p <.001, indicating that each step significantly added to the total prediction of its respective outcome measure (Tabachnick & Fidell, 2014).

Table 4. *Results from Hierarchical Regression Analyses for the Longitudinal Prediction of Morphological Awareness in Grade 1 and 2*

Step	Pre-School Predictors	*R*	R^2	Adjusted R^2	ΔR^2	ΔF	*p*
	Morphological Awareness Grade 1						
1	Morphological Awareness	.540	.292	.288	.292	79.62	<.001
2	BPVS-II	.549	.302	.294	.010	2.65	.105
3	Matrix Reasoning	.553	.306	.291	.004	0.53	.591
	Raven's CPM						
4	Backward Digit Recall	.559	.313	.291	.007	0.96	.384
	Listening Recall						
	Morphological Awareness Grade 2						
1	Morphological Awareness	.541	.292	.289	.292	79.79	<.001
2	BPVS-II	.549	.302	.294	.009	2.54	.113
3	Matrix Reasoning	.554	.307	.293	.006	0.78	.462
	Raven's CPM						
4	Backward Digit Recall	.589	.346	.326	.039	5.63	.004
	Listening Recall						

R=Multiple correlation; R^2*= amount of added variance;* ΔR^2 *= R squared change;* ΔF *= F change*

Table 5. *Multiple Regression Coefficients Grade 1 and Grade 2*

Pre-school Predictors	*B*	*β*	*t*	*Sr²*	*p*
Morphological Awareness Grade 1					
Morphological Awareness	.528	.488	6.48	.154	<.001
BPVS-II	.027	.109	1.58	.009	.118
Matrix Reasoning	−.038	−.067	−1.03	.004	.304
Raven's CPM	−.019	−.029	−0.43	.001	.670
Backward Digit Recall	−.007	−.008	−0.12	.000	.907
Listening Recall	.051	.093	1.36	.006	.117
Morphological Awareness Grade 2					
Morphological Awareness	.394	.400	5.45	.103	<.001
BPVS-II	.018	.081	1.21	.005	.229
Matrix Reasoning	−.007	−.014	−0.22	.000	.829
Raven's CPM	.027	.045	0.67	.002	.502
Backward Digit Recall	.058	.078	1.13	.004	.259
Listening Recall	.089	.180	2.69	.025	.008

B=Unstandardised Beta coefficients; β= Standardised Beta coefficients; Sr^2= Squared semipartial correlations

For the longitudinal prediction of morphological awareness in Grade 1, it can be seen that the variance accounted for by all predictors in step 4 amounted to a total of 31.3% (adjusted R^2 = .291. $F(6, 188) = 14.25$, $p < .001$). Approximately 29% of this variance was offered by the autoregressor, leaving a variance of around 2% to be accounted for by the remaining predictors. Interestingly, the autoregressor was the only step to offer a significant variance in the outcome measure. This finding is corroborated when looking at the regression coefficients displayed in Table 5, in which it can be noticed that none of the individual predictors were capable of offering a significant variance in the outcome measure, apart from the autoregressor. Consequently, after controlling for the autoregressor, receptive vocabulary, and nonverbal-IQ, working memory did not provide significant effects upon morphological awareness in Grade 1, and the variance offered was a limited 0.7% ($p = .384$).

The total amount of variance predicted in Grade 2 morphological awareness with all measures included (step 4) was slightly larger than that of Grade 1, with a variance of 34.6 % (adjusted R^2 = .326. $F(6, 188) = 5.63$, $p < .001$). The analysis showed that the autoregressor accounted for a variance of 29.2% ($p < .001$) in morphological awareness from Grade 2, leaving a variance of 5.4%. Of most interest, working memory accounted for a significant variance nearing 4 % (ΔR^2 = .039, p = .004) in Grade 2 morphological awareness when all other predictors were controlled for. Notably, the squared semipartial correlations of the working memory measures in Grade 2 analysis revealed that Backward Digit Recall on its own was incapable of providing a significant contribution to morphological awareness (Sr^2 = .004, p = .259). Listening Recall, on the other hand, offered a significant variance in morphological awareness from Grade 2, with a unique contribution of 2.5 %, p = .008. By examining the regression coefficients, it can be identified that Listening Recall was the greatest unique predictor of Grade 2 morphological awareness when excluding the autoregressor. This predictor offered a standardised coefficient of β= .180, which implies that the children who scored one standard deviation higher in the Listening Recall Task were inclined to score approximately 0.2 standard deviation units higher in the composite morphological awareness measure from Grade 2 (Field, 2018).

7. Discussion

The purpose of the present study has been to investigate whether working memory measured in pre-school would be a longitudinal predictor of morphological awareness measured in Grade 1 and Grade 2. The correlational analyses showed that both measures of working memory from pre-school significantly correlated with morphological awareness across the two grade levels. After controlling for the effect of prior morphological awareness, receptive vocabulary, and nonverbal-IQ, the hierarchical regression analyses revealed that working memory failed to significantly account for any variance in morphological awareness in Grade 1. Interestingly, for morphological awareness in Grade 2, a unique significant contribution of 4% was attributable to working memory. Whereas the magnitude of the effect in Grade 2 was modest, it was robust to the stringent statistical control of the autoregressor, receptive vocabulary, and nonverbal-IQ, providing valuable indications that working memory capacity in pre-school is a predictor of morphological awareness achievements in second grade children.

The establishment of working memory as a predictor of morphological awareness is compatible to other longitudinal research that has found working memory in young children to be a predictor of later language skills (Fitzpatrick & Pagani, 2012; Gathercole et al., 1992; Montoya et al., 2019; Newbury et al., 2016). The present study also falls in line with research to have established significant correlations between morphological knowledge and working memory (Daneman & Case, 1981; J. L. McDonald, 2008; Verhagen & Leseman, 2016). In particular, the detected relationship between working memory and morphological awareness in the present study seems consistent to the result by Verhagen and Leseman (2016), who reported significant moderate correlations between verbal working memory and expressive morphology (measured by production tasks) in five-year-old Dutch children, and in Turkish children who were Dutch language-learners. However, the study by Verhagen and Leseman employed concurrent measures in a correlational design, thus differs from the longitudinal design of the present study. A further distinction is that the study by Verhagen and Leseman tapped quite narrow aspects of morphology in the form of inflectional processes indexed by noun plurals and past participles. In contrast, the present study employed more wide-ranging measures of morphological awareness. Specifically, a meta-inflectional task was employed, which asked the children to manipulate pseudo-words by the inflection of noun plurals, present and past verbs, and adjectives. Additionally, a meta-derivational task was employed, which assessed the children's ability to manipulate real words by removal or addition of derivational suffixes. Hence, the present study is the first of its kind to explore the associations between working memory and morphological awareness operationalised as extensively by two morphological domains. Considering the high validity of the morphological awareness tasks in Norwegian (see García Grande, 2018), and the fact that this these tasks have been proven reliable measures for the longitudinal prediction of several reading outcomes in Greek (Diamanti et al., 2017), there are good grounds to believe that the present study has captured the morphological awareness construct, and contributed to an insight of the cognitive mechanisms underlying this ability in early language development.

The role of working memory in the development of morphological awareness can moreover be compared to the model postulated by Zhang et al. (2014). Through the model the authors propose that morphological awareness facilitates the storage of morphologically meaningful units as chunks; in turn, these chunks become lexical representations that can efficiently be mapped onto novel words to access meaning. As a consequence the efficiency of working memory is increased, which provides gains to vocabulary acquisition and reading comprehension. In general, the results of the present study seem accommodate such a model. However, based on the results in this study it is suggested that the capacity of the working memory is a precursor to morphological awareness achievements. Comparably, Zhang et al. (2014) propose superior morphological awareness to positively impact working memory capacity. It is plausible that the relationship between the two constructs is dynamic, which the model by Zhang et al. also accounts for. Such a reciprocal relationship is more extensively corroborated by the finding by Mainela-Arnold et al. (2012), which showed that the ability to decompose words into phonemes and stems significantly predicted individual achievements in a complex sentence-span task employed to tap working memory capacity. Although it is difficult to make claims that chunking is involved in the relationship between working memory and morphological awareness, such a theory is coherent with previous empirical investigations on the nature of working memory and language processing (Daneman & Case, 1981; Mainela-Arnold et al., 2012; Thalmann et al., 2019). Particularly the study by Daneman and Case (1981), which reported that children were able to retain pseudo-words in memory as chunks in the form of affixes and stems, could inform such an interpretation of the results. The study by Daneman and Case nevertheless diverges somewhat from the present study; the authors found significant associations between working memory and morphological analysis in younger children (aged 2-6), possibly because they did not tap metalinguistic awareness by the manipulation of word structures.

The finding of the present study shows that there is a shift in the role of working memory to morphological awareness as children develop from the first to the second grade. Furthermore, as identified by the bivariate correlations (see Table 3), the relationship between the working memory measures and morphological awareness strengthens from the first to the second grade. In more detail, Listening recall shared a correlation of $r_s = .214$ with morphological awareness in Grade 1, which improved to a correlation of $r_s = .369$ in Grade 2. Similarly, the correlation between Backward Digit Recall and morphological awareness increased from $r_s = .245$ in Grade 1 to $r_s = .320$ in Grade 2. A foundational interpretation for the better prediction of morphological awareness in Grade 2 to that in Grade 1 might therefore be that the relationship between working memory and morphological awareness strengthens as children develop and attain higher levels of morphological awareness.

As formerly outlined, morphological awareness in early school years undergoes growth. While it is evidenced that young children hold some morphological awareness, this awareness is by no means complete, as suggested by the difference in achievements across morphological domains in the production task by Berko (1958), as well as in Diamanti et al. (2018). In addition, results from studies of the development of morphological awareness provide strong evidence that morphological awareness develops with the experience of more complex forms of language (Berninger et al., 2010; Duncan et al., 2009; Ku & Anderson, 2003), and that the awareness of inflectional morphology precedes that of derivational morphology (Berko, 1958; Berninger et al., 2010; Diamanti et al., 2018; Kuo & Anderson, 2006). While limited research has been invested in the development of Norwegian morphology during early school years, the growth of morphological awareness during these years seems to be a consensus across languages, making it reasonable to assume that this trajectory also pertains to the Norwegian language. The present study has previously highlighted that children transition from implicit to more explicit levels of morphological awareness (Carlisle, 1995). Following the model by Gombert (1992), it was suggested that metalinguistic awareness develops in phases to increasingly become conscious cognitive control of various linguistic domains. Additionally, cognitive control, in the form of central executive processing, has been suggested to relate to achievements in higher order linguistic tasks (Engel de Abreu et al., 2011; Friesen & Bialystok, 2012). In compliance with this, it can be argued that as children develop their morphological awareness during early school years, they reach higher levels of metalinguistic awareness and rely more on attentional processes, exerted by executive control, during analysis and manipulation of complex linguistic structures, which in turn strains working memory capacity to a larger degree.

In attempting to more comprehensively understand the associations between working memory and morphological awareness, it can be postulated that the increase of working memory prediction relates to reading achievements, and reading comprehension in particular. This assumption is based on the fact that the development of linguistic awareness parallels reading acquisition (Seymour et al., 2003), and that morphological awareness is fundamental when inferring meaning while reading (Carlisle, 2000; Nagy & Scott, 2000). More specifically, morphological awareness enables children to analyse and decompose complex linguistic structures, and thereby facilitates vocabulary learning and reading comprehension (Nagy, Berninger, Abbott, Vaughan, & Vermeulen, 2003). In Norway formal reading instruction begins in the first grade, which means that the Grade 1 testing of the children in this study took place at the onset of formal literacy training. In beginning readers the focus lies on understanding the alphabetic principle, with attention to grapheme-phoneme correspondences. In other words, the emphasis at this stage is on the decoding of graphemes and not larger linguistic units as such (Manolitsis et al., 2019). Thus, phonological awareness has been proven a strong predictor of individual achievements in the initial stages of reading development (Melby-Lervåg, Lyster, et al., 2012). However, as children master foundational reading skills, the exposure to longer and more complex words that require analysis can help children consolidate their understanding of the relationship between morphemes and their meaning, which is likely to support reading comprehension (Duncan et al., 2009; Kirby et al., 2012; Ku & Anderson, 2003).

Taking this into account, a more hypothetical interpretation of the results might be that the children who performed well in the working memory tasks from pre-school had an advantage in their early reading development. Such an assumption corresponds to other research to evidence that working memory capacity predicts reading comprehension in early school years (Daneman & Merikle, 1996; Gathercole et al., 2003; McVay & Kane, 2012; Peng et al., 2018). Particularly the central executive has been found to be a good predictor of language comprehension (Daneman & Merikle, 1996, for a review). The meta-analysis by Peng et al. (2018) reported that the central executive was largely involved in early reading acquisition prior to Grade 4, indicating that children in their early reading development relied on their working memory for attentional processes required for decoding and comprehension. Taken together, it seems plausible that the central executive is influential when reading begins to involve morphological processing. In relation to the result of the present study, this might mean that the children who were able to focus their attention to word components for analysis while reading accelerated their awareness of morphology by virtue of their working memory capacity. The strengthening of working memory's prediction upon morphological awareness might therefore stem from the fact that both constructs are distinct but contributing factors to early language acquisition, and that these skills converge during the first school years as a result of their shared contribution to reading comprehension. Arguably, if the abovementioned inferences prove correct, the contribution of working memory to morphological awareness should remain, and perhaps also increase, across the first grade levels as children develop their reading proficiency. Thereafter, the association might decrease as children gain a richer vocabulary and rely less on executive processing during meaning construction (Peng et al., 2018). Such a pattern nonetheless remains to be determined by future studies.

A final point to be made is that the results of the present study should be interpreted in the Norwegian context. As previously outlined, Norwegian is a semi-transparent language (Seymour et al., 2003). The impact of working memory upon morphological awareness could possibly vary in conjunction with cognitive demands posed by each orthography in early reading development. Considering the cross-linguistic study by Mousikou et al. (2020) that identified morphological processing to be more involved during online reading in orthographically opaque languages (i.e. English) than in comparably more morphologically complex languages (i.e. French, German, Italian), and the fact that morphological awareness seems to contribute to reading comprehension at a later stage in English (Deacon & Kirby, 2004; Kirby et al., 2012) than in Greek (Diamanti et al., 2017), it would be interesting for future research to explore whether the obtained results hold up or prove differently across languages. Moreover, additional factors, such as the onset of formal reading instruction, might be influential to when the two constructs interact.

7.1 Implications of The Present Study

The results of this study suggest that a large working memory capacity in pre-school contributes to gains in morphological awareness measured two years later. On the flip side, children with working memory limitations are likely to be less morphological aware, meaning that they might be unsuccessful in the decomposition and analysis of morphologically complex words. As such, the children who have to process words as whole forms may face a bottleneck in terms of language and reading comprehension (Zhang et al., 2014). The results in this study therefore have some implications highly relevant for special needs educators, as well as other clinicians working with children during the course of their early language development. Evidence show that instruction in linguistic domains have significant transfer effects to verbal short-term memory (Melby-Lervåg & Hulme, 2010). In addition, morphological instruction is proven beneficial to later literacy achievements (Lyster et al. 2016), and more so in less able readers (Bowers et al., 2010). Provided this evidence, the results of the present study particularly underscore the importance of morphological instruction, in which children learn to efficiently decode the meaning of linguistic structures by their constituent morphemes; this might facilitate comprehension in those children with a restricted working memory span.

7.2 Results in Light of Validity

7.2.1 Statistical Validity

As previously outlined, statistical validity regards the strength and significance of the found effect which influences whether or not general assumptions can be made (Lund, 2002). The statistical validity in this study has been informed by a significance level of .05. Most of the correlations corresponded to a p-value of .001 or less. In addition, the found effect in morphological awareness in Grade 2 was of approximately 4%, with a p-value of .004. This indicates a 0.4% chance of the wrongful rejection of the null-hypothesis. Accordingly, the risk of having made a Type-I error in this study by rejecting the null-hypothesis when it should have been kept, is considered unlikely. Comparably, for morphological awareness in Grade 1, the variance accounted for by working memory was 0.7%, with a p-value of .384. In this case the null-hypothesis was not rejected, and taking the discrepancy between this p-value and the pre-defined significance-level into account it seems implausible that a Type-II error has been made. Whereas the sample size of the present study is relatively large (N=216), it should be mentioned that different effects might have been captured in an even larger sample (Cook & Campbell, 1979). Furthermore, the descriptive analyses identified some of the variable distributions to deviate from normality. Based on this, it was decided to estimate both parametric and nonparametric correlations. In order to further ensure that the obtained results from the statistical analyses could be considered meaningful and valid, assumptions of regression were extensively investigated as preliminary statistics to the main analyses. All assumptions were considered met for both regression analyses, which is considered a strength to the statistical validity of the results.

In general, the tests employed in the present study held high internal reliabilities, with the exception of the Meta-Derivational Task, which yielded the relatively low internal consistency coefficients of $\alpha = .65$ in pre-school, $\alpha = .61$ in Grade 1, and $\alpha = .65$ in Grade 2. Such low reliabilities could negatively impact the statistical validity, in the sense that the task might not have been appropriately successful in its consistent measurement of a single trait (i.e. meta-derivational awareness). However, considering that the Meta-derivational Task was composited with the Meta-inflectional Task, and that morphological awareness as a unitary construct held highly satisfactory reliabilities ($\alpha = .85$, $\alpha = .86$, and $\alpha = .85$, in pre-school, Grade 1, and Grade 2, respectively), it is considered probable that the tasks have been consistent in the measurement of morphological awareness as a unitary construct.

Conclusively, this study seems to hold a high reliability and statistical validity, which provides a solid foundation for the interpretation of the results.

7.2.2 Internal Validity

This study is non-experimental, which means that the causality of the identified relationship between working memory and morphological awareness cannot be accounted for (Cook & Campbell, 1979). However, hierarchical multiple regression analysis were employed as it provides some information about the prediction made by one variable upon another beyond confounding effects, which presumably strengthens the internal validity (Kleven, 2002b). Moreover, this study is longitudinal, which arguably means that it can provide stronger evidence for a causal relationship than concurrent correlational studies, seeing that the longitudinal design makes it possible to infer whether one event precedes another (Melby-Lervåg, Lyster, et al., 2012). Nonetheless, the true direction of the relationship between working memory and morphological awareness is yet to be determined by experimental research.

A measure taken to strengthen the internal validity was the statistical control of possible confounding variables. It was decided to control for the predictive effects of receptive vocabulary and nonverbal-IQ. These variables were chosen based on their empirical and theoretical with working memory and morphological awareness. Additionally, the present study included autoregressive controls to eliminate the risk of identifying a significant relationship at a certain point in time that might be due to a relation from a previous timepoint (de Jong & van der Leij, 2002). In other words, the pre-school variables presumably predicted the developmental growth in morphological awareness from the first grade onwards. It is important to state that although the effect of possible confounding factors have been attempted reduced, it is likely that the control of other factors would yield different results.

Furthermore, the children were repeatedly tested with the same tests across three timepoints. In repeated testing there is a risk of a retest effect, in which the participants might have learned something from previous test runs and therefore achieve better in the following assessment than they would have done without prior exposure to the test (Cook & Campbell, 1979). However, the tests were presented annually, and taking into account the developmental growth children endure at the respective ages, it seems unlikely that the retests have affected the results in this study. Finally, an additional threat to the internal validity in the present study might pertain to instrumentation (Lund, 2002), as there was an observed floor effect in both working memory tasks from pre-school. Listening Recall is a test with complex instructions; particularly the observed floor effect in this test could stem from confusion by the participants and/or test administrators related to how the task in itself should be carried out. If this is the case the test might not have captured the children's working memory capacity to a full extent. However, Backward Digit Recall is a test with simpler test instructions, and considering that there also was an observed floor effect in this test (albeit to a smaller degree), it seems reasonable that the scores in the working memory tests largely reflected actual results. Overall, it can be suggested that the present study holds a satisfactory internal validity.

7.2.3 Construct Validity

The variables in this study measured latent constructs, and it should therefore be considered whether the tests succeeded in measuring the traits they were employed to measure (R. P. McDonald, 2011). There are conflicting theoretical understandings of what morphological awareness is and how it should be operationalised (Apel, 2014). Morphological awareness was in this study treated as a unitary construct, in which two meta-morphological production tasks were transformed into a composite measure. These subscale tasks have been validated in Norwegian by García Grande (2018) to measure morphological awareness as an overarching construct. More specifically, in García Grande's reliability analysis it was found that the subscale measures employed in this study, together with a judgment task tapping epi-inflectional control, corresponded to morphological awareness as a single construct by 39%; meaning that the majority of variance was attributable to unknown factors, possibly other closely related (meta)linguistic skills. However, the tasks in themselves were designed to eliminate measurement error; for example, a corresponding image was presented alongside each item in order to reduce cognitive demands, and working memory involvement in particular. Additionally, pseudo-words were used in the meta-inflectional task in order to tap morphological awareness beyond vocabulary knowledge.

For the operationalisation of working memory, Listening Recall and Backward Digit Recall were taken from the standardised test-battery *WMTB-C* (Pickering & Gathercole, 2001). These tasks were employed with the intent of tapping central executive capacity. As seen in the Result chapter, the two tasks shared a variance of 10.6% (r_s= .326), and it was shown that Listening Recall uniquely and significantly predicted morphological awareness in Grade 2, while Backward Digit Recall did not. Hence, with regards to construct validity, the two tests do not seem to fully capture the same working memory traits. While this is said, the central executive is a complex and vast construct (Baddeley, 1998), meaning that the tasks could complement each other by providing a wide-ranging assessment of the same construct, and, considering the high validity of the tests (see Pickering & Gathercole, 2001), it seems reasonable to suggest that the working memory construct to some extent has been captured. A further complicating factor to the working memory tests might be that both tests are verbal, thus do not tap nonverbal executive achievements (Pickering & Gathercole, 2001). Moreover, Listening Recall demands a semantic involvement for the judgment of the veracity of each sentence. This is important to acknowledge, as it in part could have influenced why there was a found effect between Listening Recall and later morphological awareness in this study. Nonetheless, the present study controlled for verbal abilities indexed by morphological awareness and receptive vocabulary, which presumably reduced the impact of such verbal abilities to these tasks.

In regards to the control measures, receptive vocabulary was measured by *BPVS-II*, which is a standardised test normed to match Norwegian conditions (Lyster et al., 2010), and the test holds a satisfactory validity (Dunn et al., 1997). Nonverbal-IQ was measured by the test Raven's CPM (Raven, 2008), as well as Matrix Reasoning (Wechsler, 2012). Both these tests are standardised and validated. In sum, the present study seems to hold a satisfactory construct validity, despite the beforementioned limitations.

7.2.4 External Validity

The sample in this study is chosen to represent a population of pre-school, Grade 1, and Grade 2 children with Norwegian as their first language and no known learning, language, or neurological disorders. For the results in this study to be generalisable to its related population there are some considerations to be made. In general, the sampling procedure was not random, and with regards to this, the representativeness of the population is not ensured. Furthermore, the sample in this study is a convenience sample, in which all areas chosen for the recruiting were in close proximation to Oslo. This could in part weaken the external validity as the sample may represent a homogenous group of children. Such a factor was nonetheless attempted to be accommodated by recruiting children from areas assumed to represent a broad range of the population in terms of parent's education and socio-economic status. Besides, the sample size of this study is relatively large, which makes it plausible that the sample reflects some of the heterogeneity found in the respective population. Taken together, it can be suggested that the obtained result of the present study can be carefully generalised to other typically developing children within the same age range and with Norwegian as their first language. There nevertheless exists no other research to have examined the relationship between working memory and morphological awareness in Norwegian-speaking children, and additional research seems warranted to further ascertain and strengthen the generalisability of the observed results.

8. Conclusion

The results of the current study provide a preliminary insight to the role of working memory in the development of morphological awareness during early school years. Working memory capacity in pre-school was a unique significant predictor of morphological awareness in second grade children, but not in first grade children. With support from the listed literature presented in the theoretical chapters, it has been argued that working memory involvement increases in accordance with the gradual development of morphological awareness, and that working memory capacity becomes strained to a larger degree as children develop higher meta-levels of morphological awareness and make use of conscious cognitive control. Based on the fact that both working memory and morphological awareness are unique contributors to later reading comprehension, it has been proposed that the two constructs converge when reading starts to engage with morphological processing and relies on working memory involvement for attentional processes. Finally, the detected role of working memory to morphological awareness underlines the importance of providing efficient pathways to comprehension via morphological instruction, particularly to those children with a constricted working memory capacity.

8.1 Limitations

There are a few limitations to the present study that should be addressed. Importantly, the non-experimental design of this study means that conclusions about causality cannot be made, notwithstanding the fact that working memory has been identified to be a predictor of later morphological awareness.

The task choices within this study could also have posed some limitations. Firstly, although morphological awareness as an overarching construct yielded a satisfactory internal reliability, the absence of a measure of the awareness of compound morphology might be a limitation to the overall construct validity. As previously mentioned, Norwegian is a language with a rich and complex compound morphology, and to include a measure of this morphological domain might have made it possible to capture morphological awareness achievements in Norwegian children to an even larger degree. Secondly, it has been discussed that morphologically complex words might be retained in verbal short-term memory as morpheme-sized chunks; in order to explicitly investigate this, it might have been profitable to also include measures that directly tap verbal short-term memory capacities, for example by serial recall tasks that capture phonological loop capacity (Pickering & Gathercole, 2001). However, it remains unknown whether the inclusion of the mentioned tasks would provide more rewarding results. Despite the acknowledged limitations, it is believed that the present study has contributed novel and important knowledge of the role working memory plays in the development of morphological awareness across early school years.

8.2 Future Directions

Given that no other research has examined the relationship between working memory and morphological awareness, further research seems warranted to strengthen the obtained findings. This study is written in association with *NumLit*, a larger longitudinal research project, and it would be intriguing for this project to further explore the role of working memory in the development of morphological awareness across higher grade levels, particularly due to the fact that working memory seems to strengthen its prediction as children develop their morphological awareness. Lastly, it has been suggested that the predictive role of working memory might vary in compliance with cognitive demands posed by different orthographies, as well as in conjunction with the onset of formal literacy training, thus an interesting avenue for future research would be to investigate whether the obtained results prove differently across orthographies.

References

Alloway, T. P., Gathercole, S. E., Willis, C., & Adams, A.-M. (2004). A structural analysis of working memory and related cognitive skills in young children. *Journal of experimental child psychology, 87*(2), 85-106.

Apel, K. (2014). A comprehensive definition of morphological awareness: Implications for assessment. *Topics in Language Disorders, 34*(3), 197-209.

Archibald, L. M. D., & Gathercole, S. E. (2006). Short-term memory and working memory in specific language impairment. In T. Packiam Alloway & S. E. Gathercole (Eds.), *Working Memory and Neurodevelopmental Disorders* (pp. 139-160). East Sussex: Psychology Press.

Atkinson, R. C., & Shiffrin, R. M. (1968). Human memory: A proposed system and its control processes.

Baddeley, A. (1998). The central executive: A concept and some misconceptions. *Journal of the International Neuropsychological Society, 4*(5), 523-526.

Baddeley, A. (2000). The episodic buffer: a new component of working memory? *Trends in cognitive sciences, 4*(11), 417-423.

Baddeley, A. (2003). Working memory and language: An overview. *Journal of communication disorders, 36*(3), 189-208.

Baddeley, A. (2010). Working memory. *Current biology, 20*(4), R136-R140.

Baddeley, A. (2012). Working memory: Theories, models, and controversies. *Annual review of psychology, 63*, 1-29.

Baddeley, A., Gathercole, S., & Papagno, C. (1998). The phonological loop as a language learning device. *Psychological review, 105*(1), 158.

Baddeley, A., & Hitch, G. J. (1974). Working Memory. In G. A. Bower (Ed.), *Recent Advances in Learning and Motivation* (Vol. 8, pp. 47-90). New York: Academic Press.

Baddeley, A., & Hitch, G. J. (1994). Developments in the concept of working memory. *Neuropsychology, 8*(4), 485.

Baddeley, A., & Hitch, G. J. (2000). Development of working memory: Should the Pascual-Leone and the Baddeley and Hitch models be merged? *Journal of experimental child psychology, 77*(2), 128-137.

Berko, J. (1958). The child's learning of English morphology. *Word, 14*(2-3), 150-177.

Berninger, V. W., Abbott, R. D., Nagy, W., & Carlisle, J. (2010). Growth in phonological, orthographic, and morphological awareness in grades 1 to 6. *Journal of psycholinguistic research, 39*(2), 141-163.

Bialystok, E., & Ryan, E. B. (1985). Toward a definition of metalinguistic skill. *Merrill-Palmer Quarterly (1982-)*, 229-251.

Bishop, D. V., Snowling, M. J., Thompson, P. A., Greenhalgh, T., Consortium, C., Adams, C., . . . Bellair, J. (2017). Phase 2 of CATALISE: A multinational and multidisciplinary Delphi consensus study of problems with language development: Terminology. *Journal of Child Psychology and Psychiatry, 58*(10), 1068-1080.

Bowers, P. N., Kirby, J. R., & Deacon, S. H. (2010). The Effects of Morphological Instruction on Literacy Skills: A systematic review of the literature. *Review of Educational Research, 80*(2), 144-179. doi:10.3102/0034654309359353

Broadbent, D. E. (1958). *Perception and Communication*. London: Pergamont.

Burger, A., & Chong, I. (2011). Receptive vocabulary. *Encyclopedia of child behavior and development*, 1231-1231.

Carlisle, J. F. (1995). Morphological awareness and early reading achievement. In L. B. Feldman (Ed.), *Morphological aspects of language processing*. New Jersey: Lawrence Erlbaum Associates, Inc.

Carlisle, J. F. (2000). Awareness of the structure and meaning of morphologically complex words: Impact on reading. *Reading and Writing: An Interdisciplinary Journal, 12*, 169-190.

Carlisle, J. F. (2003). Morphology matters in learning to read: A commentary. *Reading Psychology, 24*(3-4), 291-322.

Carlisle, J. F. (2007). Fostering morphological processing, vocabulary development, and reading comprehension. In R. K. Wager, A. E. Muse, & K. R. Tannenbaum (Eds.), *Vocabulary acquisition: Implications for reading comprehension* (pp. 78-103). New York: Guildford Press.

Carlisle, J. F. (2010). Effects of instruction in morphological awareness on literacy achievement: An integrative review. *Reading research quarterly, 45*(4), 464-487.

Carlisle, J. F., & Nomanbhoy, D. M. (1993). Phonological and morphological awareness in first graders. *Applied psycholinguistics, 14*(2), 177-195.

Carlisle, J. F., & Stone, C. A. (2005). Exploring the role of morphemes in word reading. *Reading research quarterly, 40*(4), 428-449.

Carlisle, J. F., Stone, C. A., & Katz, L. A. (2001). The effects of phonological transparency on reading derived words. *Annals of dyslexia, 51*(1), 249-274.

Chen, Z., & Cowan, N. (2005). Chunk limits and length limits in immediate recall: a reconciliation. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 31*(6), 1235.

Clahsen, H., Sonnenstuhl, I., & Blevins, J. P. (2003). Derivational morphology in the German mental lexicon: A dual mechanism account. *TRENDS IN LINGUISTICS STUDIES AND MONOGRAPHS, 151*, 125-156.

Cohen, L., Manion, L., & Morrison, K. (2007). *Research Methods in Education* (6th ed.). New York: Routledge.

Cohen, L., Manion, L., & Morrison, K. (2018). *Research Methods in Education* (8th ed.). London: Routledge.

Cohen, R. J., & Swerdlik, M. E. (2018). *Psychological testing and assessment: An introduction to tests and measurement* (9th ed.). Boston: McGraw-Hill.

Cook, T. D., & Campbell, D. T. (1979). *Quasi-experimentation : design & analysis issues for field settings*. Boston: Houghton Mifflin Co.

Cowan, N. (2001). The magical number 4 in short-term memory: A reconsideration of mental storage capacity. *Behavioral and brain sciences, 24*(1), 87-114.

Cowan, N. (2008). What are the differences between long-term, short-term, and working memory? In W. S. Sossin, J.-C. Lacaille, V. F. Castellucci, & S. Belleville (Eds.), *Progress in Brain Research* (Vol. 169): Elsevier.

Cowan, N. (2014). Working memory underpins cognitive development, learning, and education. *Educational psychology review, 26*(2), 197-223.

Creswell, J. W., & Creswell, J. D. (2018). *Research design : qualitative, quantitative & mixed methods approaches* (5th ed.). Los Angeles, California: Sage.

Cumming, G., & Calin-Jageman, R. (2017). *Introduction to the new statistics*. New York: Routledge.

Cunningham, A. J., & Carroll, J. M. (2015). Early predictors of phonological and morphological awareness and the link with reading: Evidence from children with different patterns of early deficit. *Applied psycholinguistics, 36*(3), 509-531.

Daneman, M., & Carpenter, P. A. (1980). Individual differences in working memory and reading. *Journal of Memory and Language, 19*(4), 450.

Daneman, M., & Case, R. (1981). Syntactic form, semantic complexity, and short-term memory: Influences on children's acquisition of new linguistic structures. *Developmental psychology, 17*(4), 367.

Daneman, M., & Merikle, P. M. (1996). Working memory and language comprehension: A meta-analysis. *Psychonomic bulletin & review, 3*(4), 422-433.

de Jong, P. F., & van der Leij, A. (2002). Effects of phonological abilities and linguistic comprehension on the development of reading. *Scientific Studies of Reading, 6*(1), 51-77.

Deacon, S. H., & Kirby, J. R. (2004). Morphological awareness: Just "more phonological"? The roles of morphological and phonological awareness in reading development. *Applied psycholinguistics, 25*(2), 223-238.

Diamanti, V., Benaki, A., Mouzaki, A., Ralli, A., Antoniou, F., Papaioannou, S., & Protopapas, A. (2018). Development of early morphological awareness in Greek: Epilinguistic versus metalinguistic and inflectional versus derivational awareness. *Applied psycholinguistics, 39*(3), 545-567.

Diamanti, V., Mouzaki, A., Ralli, A., Antoniou, F., Papaioannou, S., & Protopapas, A. (2017). Preschool phonological and morphological awareness as longitudinal predictors of early reading and spelling development in Greek. *Frontiers in psychology, 8*, 2039.

Duncan, L. G. (2018). Language and Reading: the Role of Morpheme and Phoneme Awareness. *Current developmental disorders reports, 5*(4), 226-234.

Duncan, L. G., Casalis, S., & Colé, P. (2009). Early metalinguistic awareness of derivational morphology: Observations from a comparison of English and French. *Applied psycholinguistics, 30*(3), 405-440.

Dunn, L. M., & Dunn, D. M. (2009). *The British picture vocabulary scale*: GL Assessment Limited.

Ellis, N. C., & Sinclair, S. G. (1996). Working memory in the acquisition of vocabulary and syntax: Putting language in good order. *The Quarterly Journal of Experimental Psychology Section A, 49*(1), 234-250.

Engel de Abreu, P. M. J., Gathercole, S. E., & Martin, R. (2011). Disentangling the relationship between working memory and language: The roles of short-term storage and cognitive control. *Learning and Individual Differences, 21*, 569-574. doi:10.1016/j.lindif.2011.06.002

Engle, R. W. (2002). Working memory capacity as executive attention. *Current directions in psychological science, 11*(1), 19-23.

Evans, J. L., Gillam, R. B., & Montgomery, J. W. (2018). Cognitive predictors of spoken word recognition in children with and without developmental language disorders. *Journal of Speech, Language, and Hearing Research, 61*(6), 1409-1425.

Fejzo, A., Desrochers, A., & Deacon, S. H. (2018). The Acquisition of Derivational Morphology in Children. In R. Berthiaume, D. Daigle, & A. Desrochers (Eds.), *Morphological Processing and Literacy Development* (pp. 112-132). New York: Routledge.

Feldman, L. B., & Milin, P. (2018). Psycholinguistic Studies of Word Morphology and Their Implications for Models of the Mental Lexicon and Lexical Processing. In R. Berthiaume, D. Daigle, & A. Desrochers (Eds.), *Morphological Processing and Literacy Development* (pp. 16-47). New York: Routledge.

Field, A. (2018). *Discovering Statistics Using IBM SPSS Statistics* (5th ed.). London: SAGE Publications Inc.

Fitzpatrick, C., & Pagani, L. S. (2012). Toddler working memory skills predict kindergarten school readiness. *Intelligence, 40*(2), 205-212.

Friesen, D. C., & Bialystok, E. (2012). Metalinguistic ability in bilingual children: The role of executive control. *Rivista di psicolinguistica applicata, 12*(3), 47.

Gall, M. D., Gall, J. P., & Borg, W. R. (2003). *Educational Research: An Introduction* (8th ed.). Boston: Allyn and Bacon.

García Grande, G. (2018). *Morphological awareness in Norwegian Pre-schoolers.* (Unpublished Master Thesis). University of Oslo, Oslo.

Gathercole, S. E. (1998). The development of memory. *The Journal of Child Psychology and Psychiatry and Allied Disciplines, 39*(1), 3-27.

Gathercole, S. E. (1999). Cognitive approaches to the development of short-term memory. *Trends in cognitive sciences, 3*(11), 410-419.

Gathercole, S. E., Brown, L., & Pickering, S. J. (2003). Working memory assessments at school entry as longitudinal predictors of National Curriculum attainment levels. *Educational and Child Psychology, 20*(3), 109-122.

Gathercole, S. E., Pickering, S. J., Ambridge, B., & Wearing, H. (2004). The structure of working memory from 4 to 15 years of age. *Developmental psychology, 40*(2), 177.

Gathercole, S. E., Willis, C. S., Emslie, H., & Baddeley, A. D. (1992). Phonological memory and vocabulary development during the early school years: A longitudinal study. *Developmental psychology, 28*(5), 887.

Giofrè, D., Mammarella, I. C., & Cornoldi, C. (2013). The structure of working memory and how it relates to intelligence in children. *Intelligence, 41*(5), 396-406.

Gombert, J. E. (1992). *Metalinguistic development*: University of Chicago Press.

Gombert, J. E. (1993). Metacognition, metalanguage and metapragmatics. *International Journal of psychology, 28*(5), 571-580.

Gonnerman, L. M. (2018). A Linguistic Analysis of Word Morphology. In R. Berthiaume, D. Daigle, & A. Desrochers (Eds.), *Morphological Processing and Literacy Development* (pp. 3-16). New York: Routledge.

Henry, L. A., & Botting, N. (2017). Working memory and developmental language impairments. *Child Language Teaching and Therapy, 33*(1), 19-32.

Henry, L. A., & Millar, S. (1991). Memory span increase with age: A test of two hypotheses. *Journal of experimental child psychology, 51*(3), 459-484.

IBM. (2019). *IBM SPSS Statistics for Macintosh, Version 26.0*. New York: IBM Corp.

Jackson, E., Leitao, S., & Claessen, M. (2016). The relationship between phonological short-term memory, receptive vocabulary, and fast mapping in children with specific language impairment. *International Journal of Language & Communication Disorders, 51*(1), 61-73.

Jackson, E., Leitao, S., Claessen, M., & Boyes, M. (2019). Fast mapping short and long words: Examining the influence of phonological short-term memory and receptive vocabulary in children with developmental language disorder. *Journal of communication disorders, 79*, 11-23.

Johann, V., Könen, T., & Karbach, J. (2019). The unique contribution of working memory, inhibition, cognitive flexibility, and intelligence to reading comprehension and reading speed. *Child Neuropsychology*, 1-21.

Karmiloff-Smith, A. (1986). From meta-processes to conscious access: Evidence from children's metalinguistic and repair data. *Cognition, 23*(2), 95-147.

Kidd, E. (2013). The role of verbal working memory in children's sentence comprehension: A critical review. *Topics in Language Disorders, 33*(3), 208-223.

Kim, Y. S. G., Guo, Q., Liu, Y., Peng, Y., & Yang, L. (2019). Multiple pathways by which compounding morphological awareness is related to reading comprehension: Evidence from Chinese second graders. *Reading research quarterly*.

Kirby, J. R., & Bowers, P. N. (2018). The Effects of Morphological Instruction on Vocabulary Learning, Reading, and Spelling. In R. Berthiaume, D. Daigle, & A. Desrochers (Eds.), *Morphological Processing and Literacy Development*. New York: Routledge.

Kirby, J. R., Deacon, S. H., Bowers, P. N., Izenberg, L., Wade-Woolley, L., & Parrila, R. (2012). Children's morphological awareness and reading ability. *Reading and writing, 25*(2), 389-410.

Kleven, T. A. (2002a). Begrepsoperasjonalisering. In T. Lund (Ed.), *Innføring i forskningsmetodologi*. Bergen: Fagbokforlaget Vigmostad & Bjørke AS.

Kleven, T. A. (2002b). Ikke-eksperimentelle design. In T. Lund (Ed.), *Innføring i forskningsmetodologi*. Bergen: Fagbokforlaget Vigmostad & Bjørke AS.

Ku, Y.-M., & Anderson, R. C. (2003). Development of morphological awareness in Chinese and English. *Reading and writing, 16*(5), 399-422.

Kuo, L.-j., & Anderson, R. C. (2006). Morphological awareness and learning to read: A cross-language perspective. *Educational psychologist, 41*(3), 161-180.

Lund, T. (2002). Metodologiske prinsipper og referanserammer. In T. Lund (Ed.), *Innføring i forskningsmetodologi*. Bergen: Fagbokforlaget.

Lyster, S.-A. H. (2002). The effects of morphological versus phonological awareness training in kindergarten on reading development. *Reading and writing, 15*(3-4), 261-294.

Lyster, S.-A. H., Horn, E., & Rygvold, A.-L. (2010). Ordforråd og ordforrådsutvikling hos norske barn og unge. Resultater fra en utprøving av British Picture Vocabulary Scale, (BPVS II). *Spesialpedagogikk, 9*, 35-43.

Lyster, S.-A. H., Lervåg, A. O., & Hulme, C. (2016). Preschool morphological training produces long-term improvements in reading comprehension. *Reading and writing, 29*(6), 1269-1288.

Mahony, D., Singson, M., & Mann, V. (2000). Reading ability and sensitivity to morphological relations. *Reading and writing, 12*(3), 191-218.

Mainela-Arnold, E., Misra, M., Miller, C., Poll, G. H., & Park, J. S. (2012). Investigating sentence processing and language segmentation in explaining children's performance on a sentence-span task. *International Journal of Language & Communication Disorders, 47*(2), 166-175.

Majerus, S., & Van der Linden, M. (2003). Long-term memory effects on verbal short-term memory: A replication study. *British Journal of Developmental Psychology, 21*(2), 303-310.

Manolitsis, G., Georgiou, G. K., Inoue, T., & Parrila, R. (2019). Are morphological awareness and literacy skills reciprocally related? Evidence from a cross-linguistic study. *Journal of Educational Psychology, 111*(8), 1362.

Mathy, F., & Friedman, O. (2020). Working memory develops at a similar rate across diverse stimuli. *Journal of experimental child psychology, 191*, 104735.

Maynard, C., Brissaud, C., & Armand, F. (2018). The Acquisition of Inflectional Morphology in Children. In R. Berthiaume, D. Daigle, & A. Desrochers (Eds.), *Morphological Processing and Literact Development*. New York: Routledge.

McBride–Chang, C., Wagner, R. K., Muse, A., Chow, B. W.-Y., & Shu, H. (2005). The role of morphological awareness in children's vocabulary acquisition in English. *Applied psycholinguistics, 26*(3), 415-435.

McDonald, J. L. (2008). Grammaticality judgments in children: The role of age, working memory and phonological ability. *Journal of child language, 35*(2), 247-268. doi:10.1017/S0305000907008367

McDonald, R. P. (2011). *Test Theory: A Unified Treatment*. New York: Routledge.

McVay, J. C., & Kane, M. J. (2012). Why does working memory capacity predict variation in reading comprehension? On the influence of mind wandering and executive attention. *Journal of experimental psychology: general, 141*(2), 302.

Melby-Lervåg, M., & Hulme, C. (2010). Serial and free recall in children can be improved by training: Evidence for the importance of phonological and semantic representations in immediate memory tasks. *Psychological science, 21*(11), 1694-1700.

Melby-Lervåg, M., & Hulme, C. (2013). Is working memory training effective? A meta-analytic review. *Developmental psychology, 49*(2), 270.

Melby-Lervåg, M., Lervåg, A., Lyster, S.-A. H., Klem, M., Hagtvet, B., & Hulme, C. (2012). Nonword-repetition ability does not appear to be a causal influence on children’s vocabulary development. *Psychological science, 23*(10), 1092-1098.

Melby-Lervåg, M., Lyster, S.-A. H., & Hulme, C. (2012). Phonological skills and their role in learning to read: a meta-analytic review. *Psychological bulletin, 138*(2), 322.

Miller, G. A. (1956). The magical number seven, plus or minus two: Some limits on our capacity for processing information. *Psychological review, 63*(2), 81.

Montoya, M. F., Susperreguy, M. I., Dinarte, L., Morrison, F. J., San Martin, E., Rojas-Barahona, C. A., & Förster, C. E. (2019). Executive function in Chilean preschool children: Do short-term memory, working memory, and response inhibition contribute differentially to early academic skills? *Early Childhood Research Quarterly, 46*, 187-200.

Mousikou, P., Beyersmann, E., Ktori, M., Javourey-Drevet, L., Crepaldi, D., Ziegler, J. C., . . . Schroeder, S. (2020). Orthographic consistency influences morphological processing in reading aloud: Evidence from a cross-linguistic study. *Developmental Science*.

Nagy, W. E., Berninger, V., Abbott, R., Vaughan, K., & Vermeulen, K. (2003). Relationship of morphology and other language skills to literacy skills in at-risk second-grade readers and at-risk fourth-grade writers. *Journal of Educational Psychology, 95*(4), 730.

Nagy, W. E., Carlisle, J. F., & Goodwin, A. P. (2014). Morphological knowledge and literacy acquisition. *Journal of Learning Disabilities, 47*(1), 3-12.

Nagy, W. E., & Scott, J. A. (2000). Vocabulary processes. In M. Kamil, P. Mosenthal, P. D. Pearson, & R. Barr (Eds.), *Handbook of reading research* (Vol. 3, pp. 269-284). New Jersey: Lawrence Erlbaum Associates.

NESH. (2016). Forskningsetiske retningslinjer for samfunnsvitenskapelige, humaniora, juss og teologi. In. Oslo: Oktan Forlag.

Newbury, J., Klee, T., Stokes, S. F., & Moran, C. (2016). Interrelationships between working memory, processing speed, and language development in the age range 2–4 years. *Journal of Speech, Language, and Hearing Research, 59*(5), 1146-1158.

Norris, D., Kalm, K., & Hall, J. (2019). Chunking and redintegration in verbal short-term memory. *Journal of Experimental Psychology: Learning, Memory, and Cognition*.

Oakhill, J., & Kyle, F. (2000). The relation between phonological awareness and working memory. *Journal of experimental child psychology, 75*(2), 152-164.

Parrila, R., Kirby, J. R., & McQuarrie, L. (2004). Articulation rate, naming speed, verbal short-term memory, and phonological awareness: Longitudinal predictors of early reading development? *Scientific Studies of Reading, 8*(1), 3-26.

Peng, P., Barnes, M., Wang, C., Wang, W., Li, S., Swanson, H. L., . . . Tao, S. (2018). A meta-analysis on the relation between reading and working memory. *Psychological bulletin, 144*(1), 48.

Pickering, S. (2006). Working memory in dyslexia. In T. P. Alloway & S. Gathercole (Eds.), *Working Memory and Neurodevelopmental Disorders*. New York: Psychology Press.

Pickering, S., & Gathercole, S. (2001). *Working Memory Test Battery for Children (WMTB-C): Manual*. London: The Psychological Corporation.

Pickering, S., & Gathercole, S. (2004). Distinctive working memory profiles in children with special educational needs. *Educational Psychology, 24*(3), 393-408.

Ragnarsdóttir, H., Simonsen, H. G., & Plunkett, K. (1999). The acquisition of past tense morphology in Icelandic and Norwegian children: An experimental study. *Journal of child language, 26*(3), 577-618.

Raven, J. (2008). General Introduction and Overview: The Raven Progressive Matrices Tests: Their theoretical basis and measurement model. In J. Raven, J. Raven, & J. Raven (Eds.), *Uses and Abuses of Intelligence: Studies Advancing Spearman and Raven's Quest for Non-Arbitrary Metrics* (pp. 17-68). New York: Unionville.

Reichle, E. D., & Perfetti, C. A. (2003). Morphology in word identification: A word-experience model that accounts for morpheme frequency effects. *Scientific Studies of Reading, 7*(3), 219-237.

Roever, C., & Phakiti, A. (2018). *Quantitative Methods for Second Language Research: A Problem Solving Approach* (1 ed.). New York: Routledge.

Roodenrys, S., & Hinton, M. (2002). Sublexical or lexical effects on serial recall of nonwords? *Journal of Experimental Psychology: Learning, Memory, and Cognition, 28*(1), 29.

Roodenrys, S., Hulme, C., & Brown, G. (1993). The development of short-term memory span: Separable effects of speech rate and long-term memory. *Journal of experimental child psychology, 56*(3), 431-442.

Seymour, P. H., Aro, M., & Erskine, J. M. (2003). Foundation literacy acquisition in European orthographies. *British Journal of psychology, 94*(2), 143-174.

Siu, T.-S. C., McBride, C., Tse, C.-S., Tong, X., & Maurer, U. (2018). Evaluating the effects of metalinguistic and working memory training on reading fluency in Chinese and English: A randomized controlled trial. *Frontiers in psychology, 9*.

Sparks, E., & Deacon, S. H. (2015). Morphological awareness and vocabulary acquisition: A longitudinal examination of their relationship in English-speaking children. *Applied psycholinguistics, 36*(2), 299-321.

Spencer, M., Muse, A., Wagner, R. K., Foorman, B., Petscher, Y., Schatschneider, C., . . . Bishop, M. D. (2015). Examining the underlying dimensions of morphological awareness and vocabulary knowledge. *Reading and writing, 28*(7), 959-988.

Stokes, S. F., Klee, T., Kornisch, M., & Furlong, L. (2017). Visuospatial and Verbal Short-Term Memory Correlates of Vocabulary Ability in Preschool Children. *Journal of Speech, Language, and Hearing Research, 60*(8), 2249-2258.

Tabachnick, B. G., & Fidell, L. S. (2014). *Using multivariate statistics: Pearson New International Edition* (6th ed.). Essex: Pearson Education Limited.

Taft, M., & Forster, K. I. (1975). Lexical storage and retrieval of prefixed words. *Journal of verbal learning and verbal behavior, 14*(6), 638-647.

Thalmann, M., Souza, A. S., & Oberauer, K. (2019). How does chunking help working memory? *Journal of Experimental Psychology: Learning, Memory, and Cognition, 45*(1), 37.

The Jamovi Project. (2020). Jamovi (Version 1.2). Retrieved from https://www.jamovi.org

Ullman, M. T., Earle, F. S., Walenski, M., & Janacsek, K. (2020). The neurocognition of developmental disorders of language. *Annual review of psychology, 71*.

Van Kleeck, A. (1982). The emergence of linguistic awareness: A cognitive framework. *Merrill-Palmer Quarterly (1982-)*, 237-265.

Verhagen, J., & Leseman, P. (2016). How do verbal short-term memory and working memory relate to the acquisition of vocabulary and grammar? A comparison between first and second language learners. *Journal of experimental child psychology, 141*, 65-82.

Wechsler, D. (2012). *WPPSI-IV. Wechsler Preschool and Primary Scale of Intelligence - Fourth Editon: Manual*: Pearson Education Inc.

Yarian, M., Washington, K. N., Spencer, C. E., Vannest, J., & Crowe, K. (2019). Exploring Predictors of Expressive Grammar Across Different Assessment Tasks in Preschoolers With or Without DLD. *Communication Disorders Quarterly*, 1525740119868238.

Zhang, J., Lin, T.-J., Wei, J., & Anderson, R. C. (2014). Morphological awareness and learning to read Chinese and English. In X. Chen, Q. Wang, & Y. Luo (Eds.), *Reading development and difficulties in monolingual and bilingual Chinese children* (pp. 3-22). New York: Springer.

Zhang, J., & Shulley, L. (2017). Poor comprehenders in English-only and English language learners: influence of morphological analysis during incidental word learning. *Journal of Research in Reading, 40*(2), 169-183.

Appendix 1: Normal Q-Q-plots of the Variables

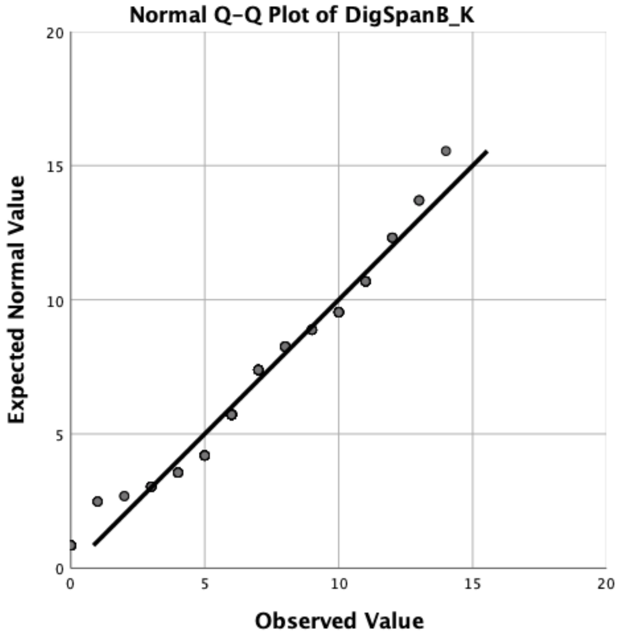

Figure 20. *Q-Q-plot: Backward Digit Recall Pre-school*

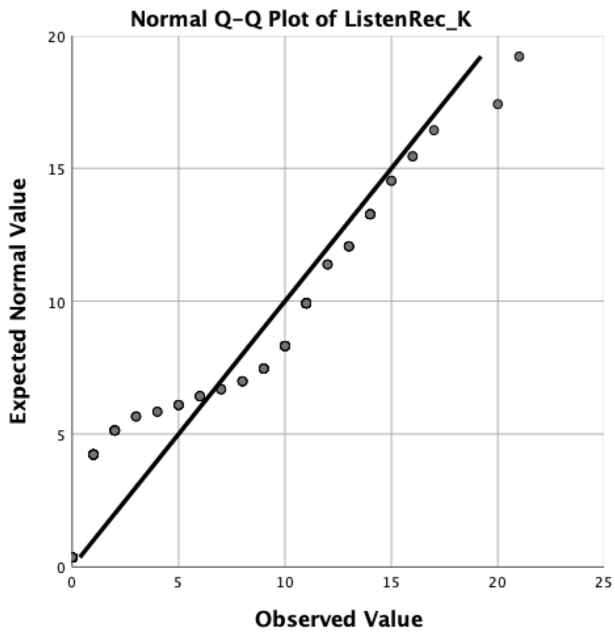

Figure 21. *Q-Q-plot: Listening Recall Pre-school*

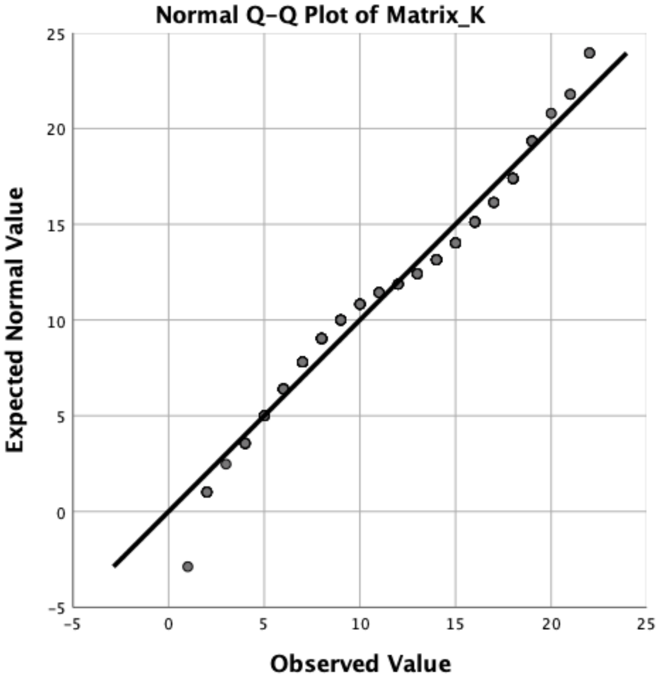

Figure 22. Q-Q-plot: Matrix Pre-school

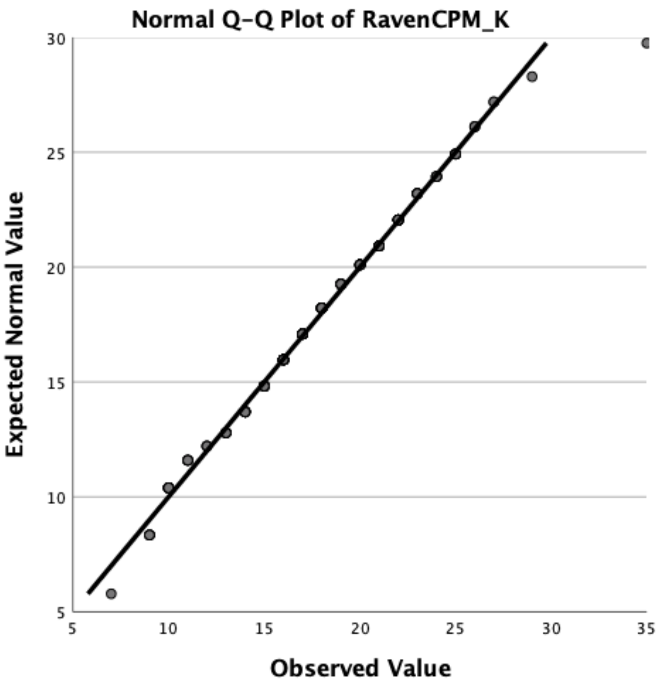

Figure 23. *Q-Q-plot: Raven‘s CPM Pre-school*

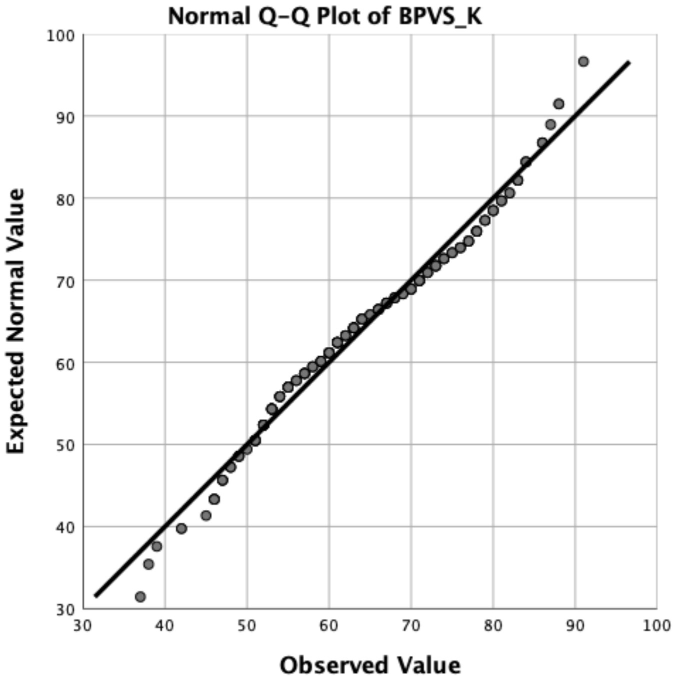

Figure 24. *Q-Q-plot: BPVS-II Pre-school*

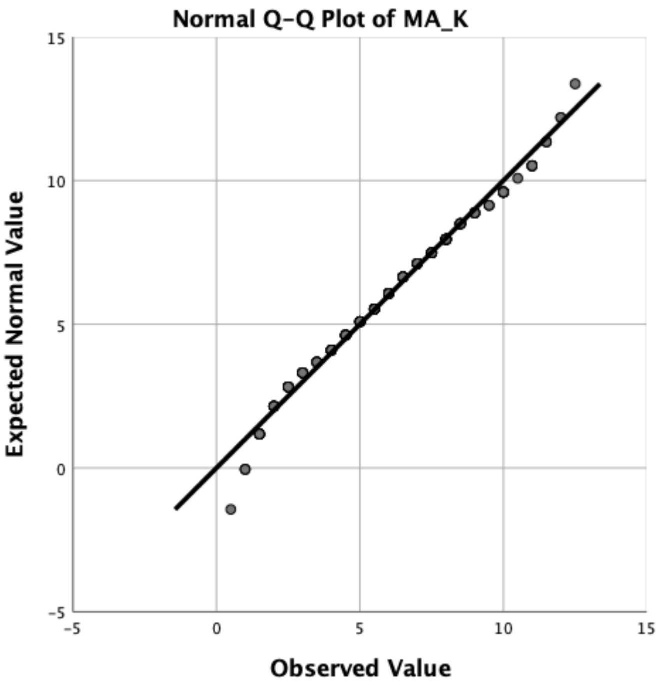

Figure 25. *Q-Q-plot: Morphological Awareness Composite Pre-school*

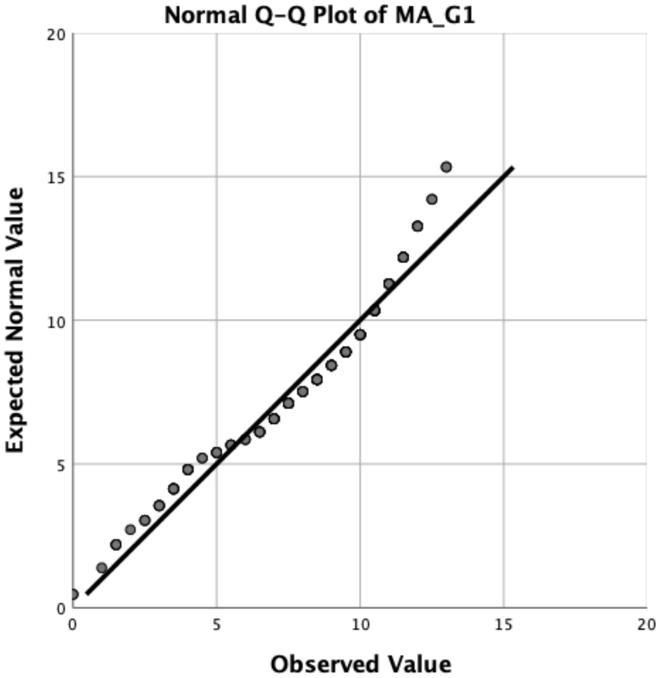

Figure 26. *Q-Q-plot: Morphological Awareness Composite Grade 1*

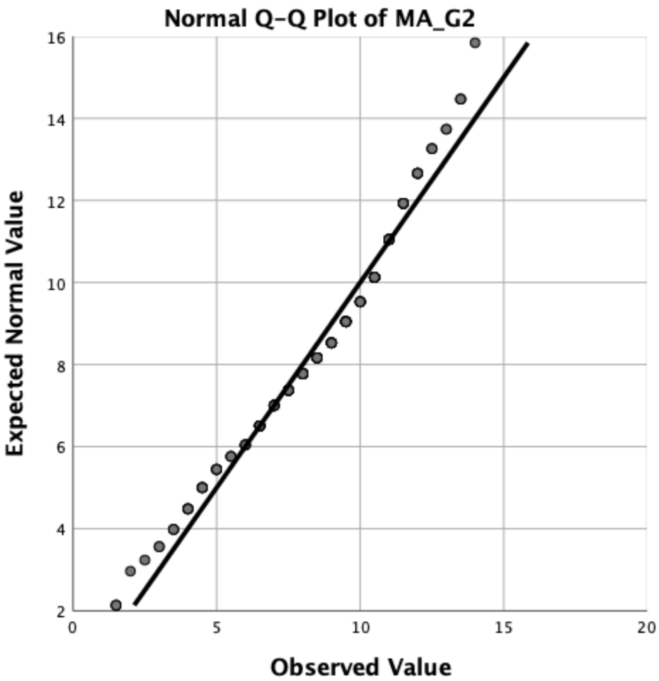

Figure 27. *Q-Q-plot: Morphological Awareness Composite Grade 2*

Appendix 2: Partial Regression Plots for Grade 1 Outcome

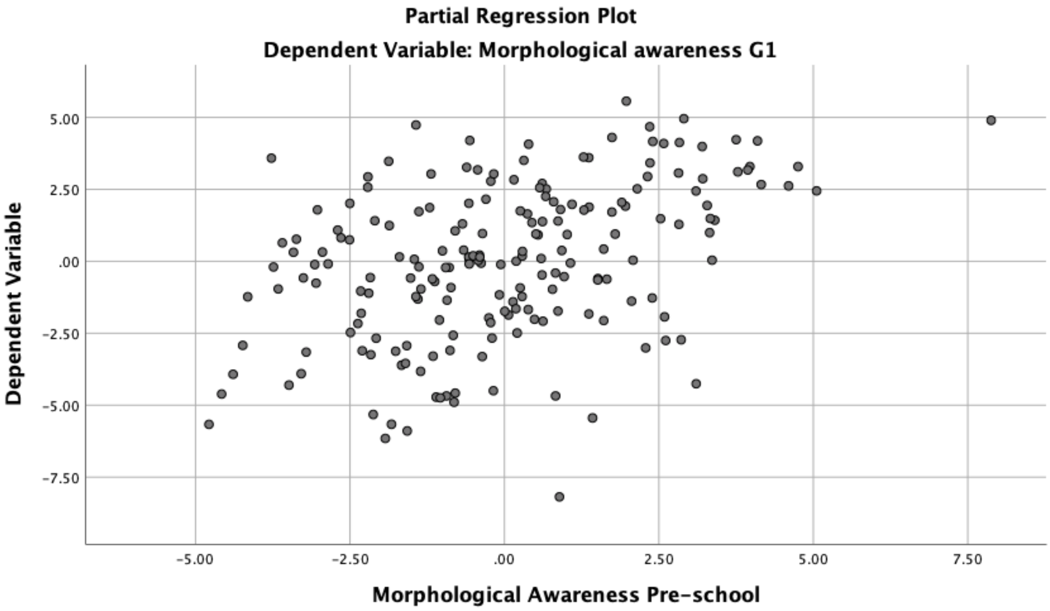

Figure 28. *Partial Regression Plot Grade 1 Outcome: Autoregressor*

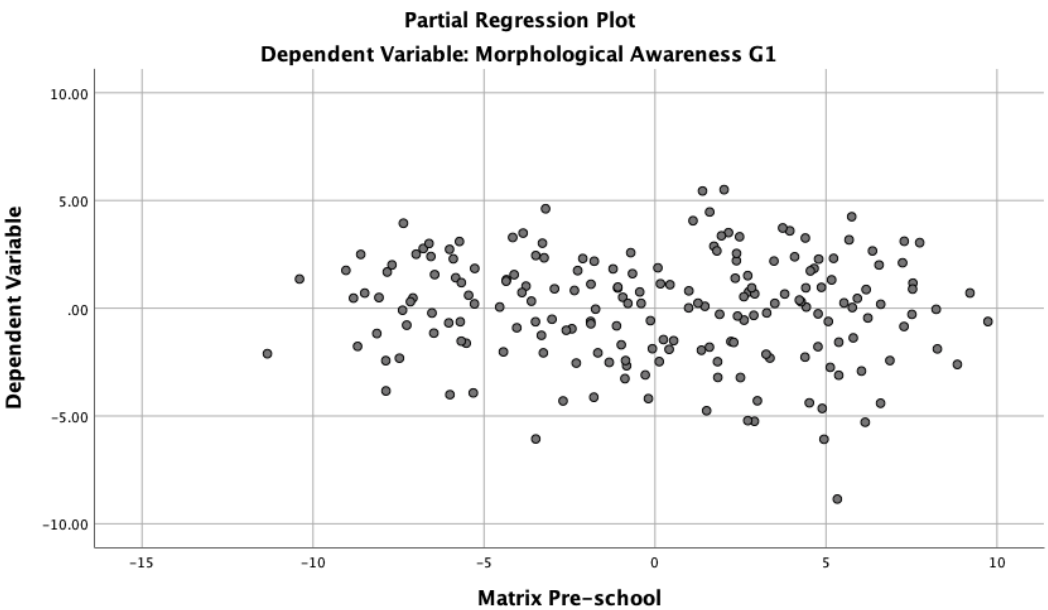

Figure 29. *Partial Regression Plot Grade 1 Outcome: Matrix*

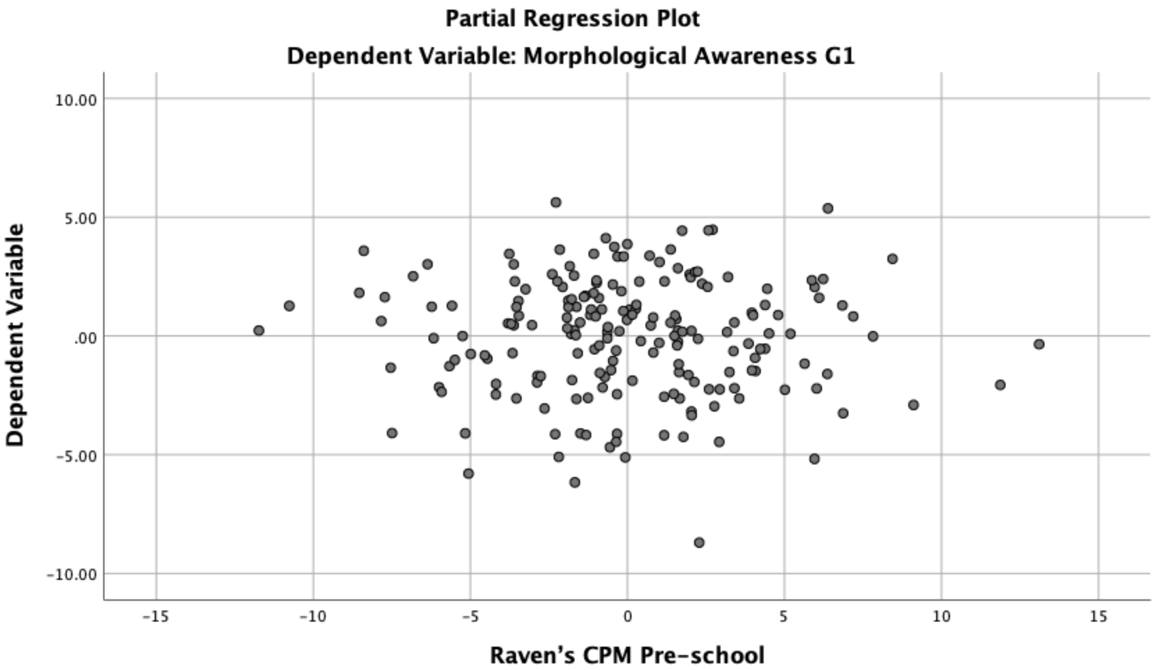

Figure 30. *Partial Regression Plot Grade 1 Outcome: Raven's CPM*

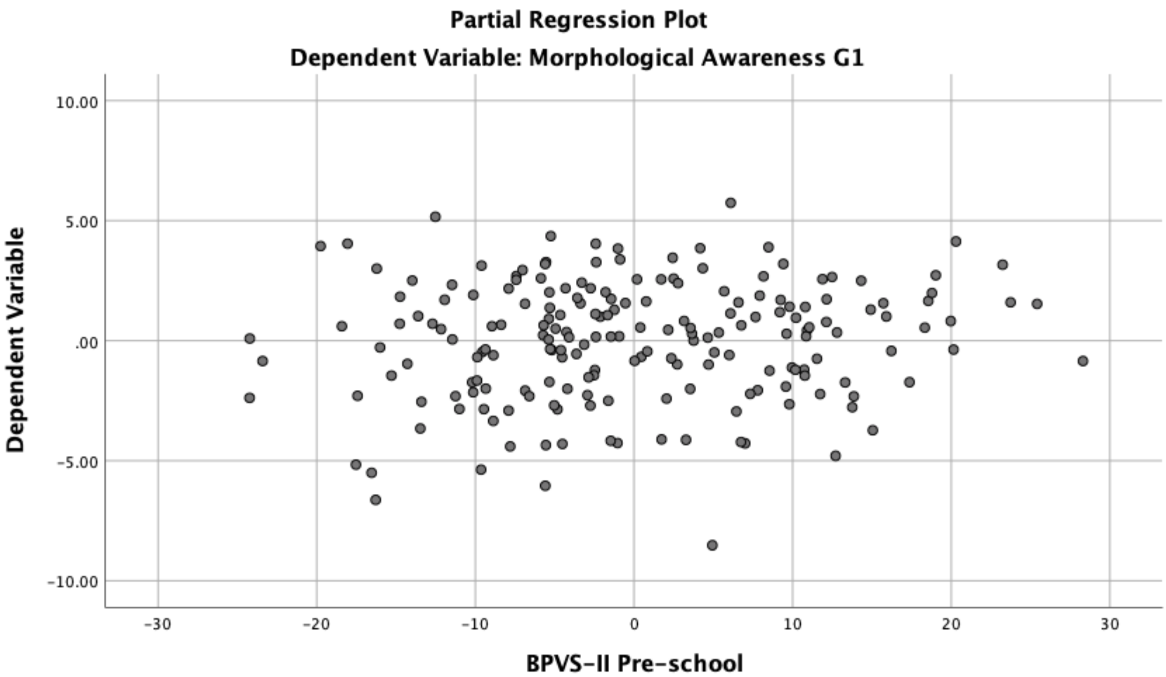

Figure 31. *Partial Regression Plot Grade 1 Outcome: BPVS-II*

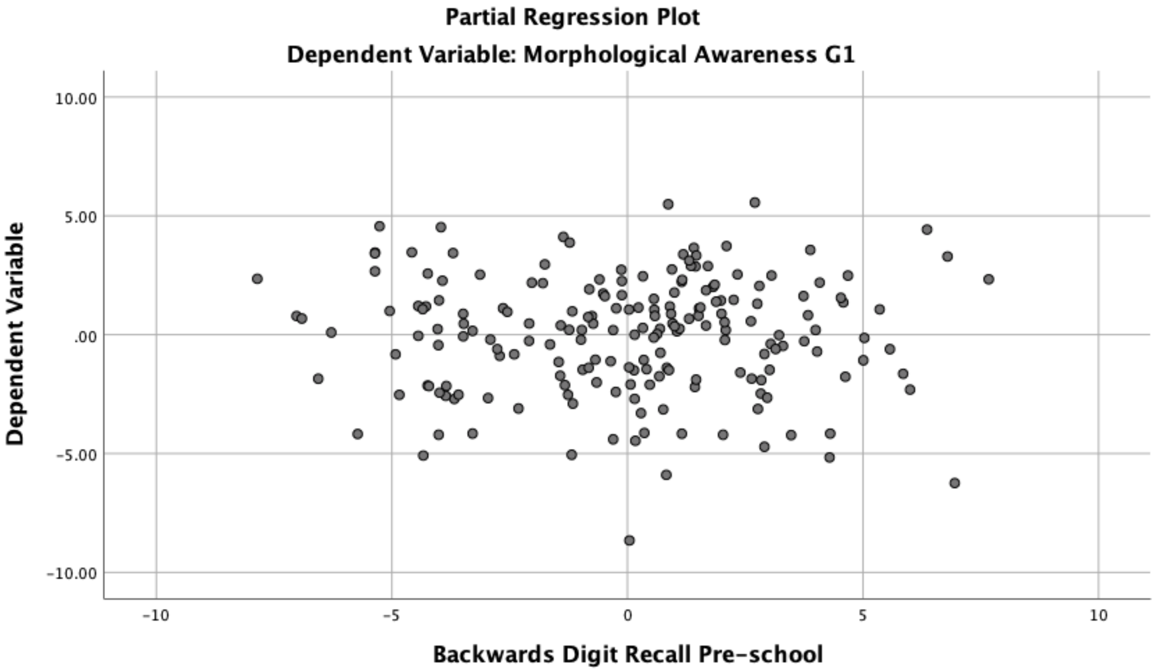

Figure 32. *Partial Regression Plot Grade 1 Outcome: Backward Digit Recall*

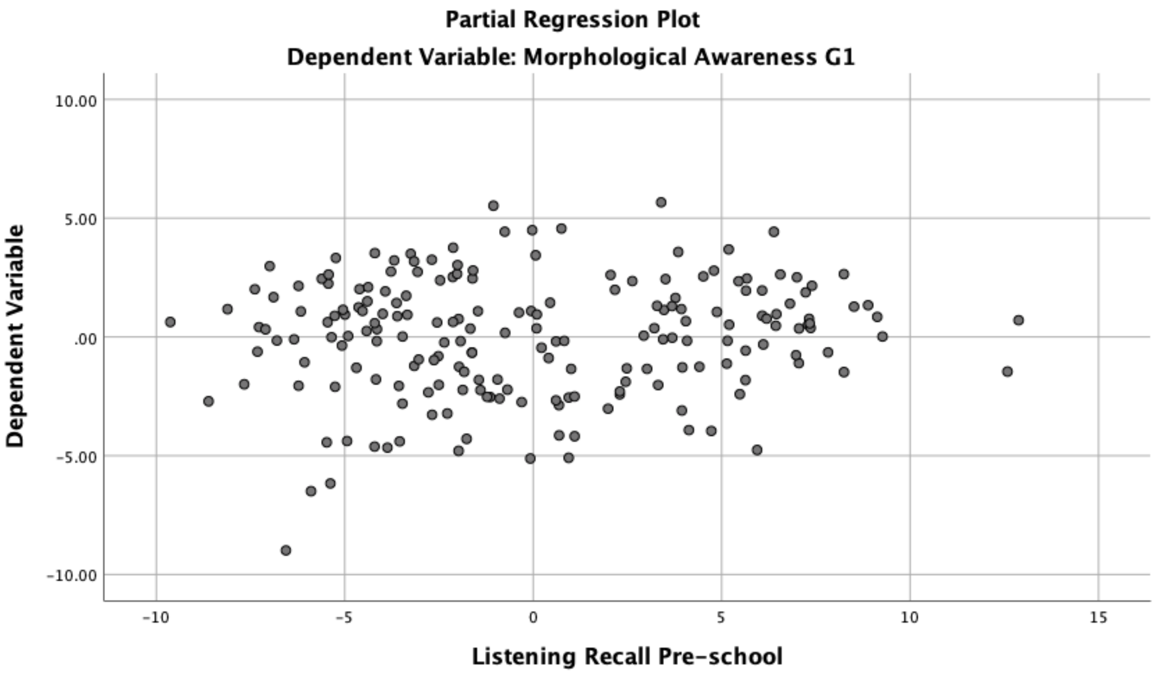

Figure 33. *Partial Regression Plot Grade 1 Outcome: Listening Recall*

Appendix 3: Partial Regression Plots for Grade 2 Outcome

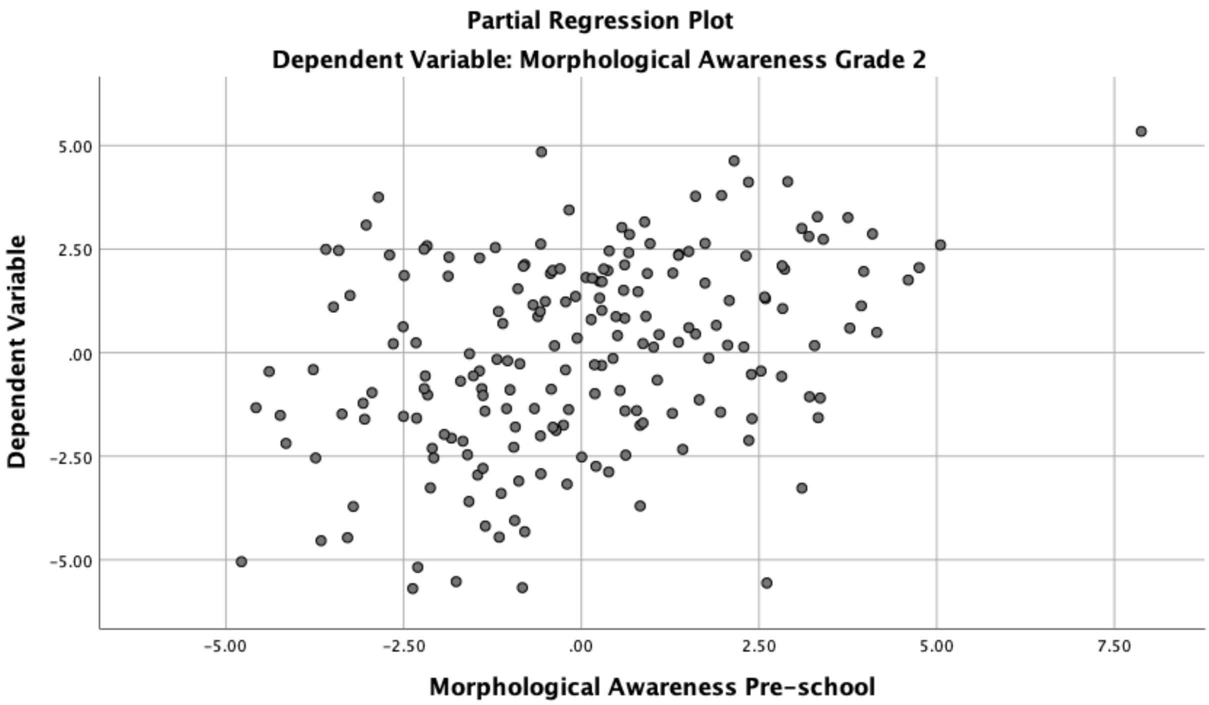

Figure 34. *Partial Regression Plot Grade 2 Outcome: Autoregressor*

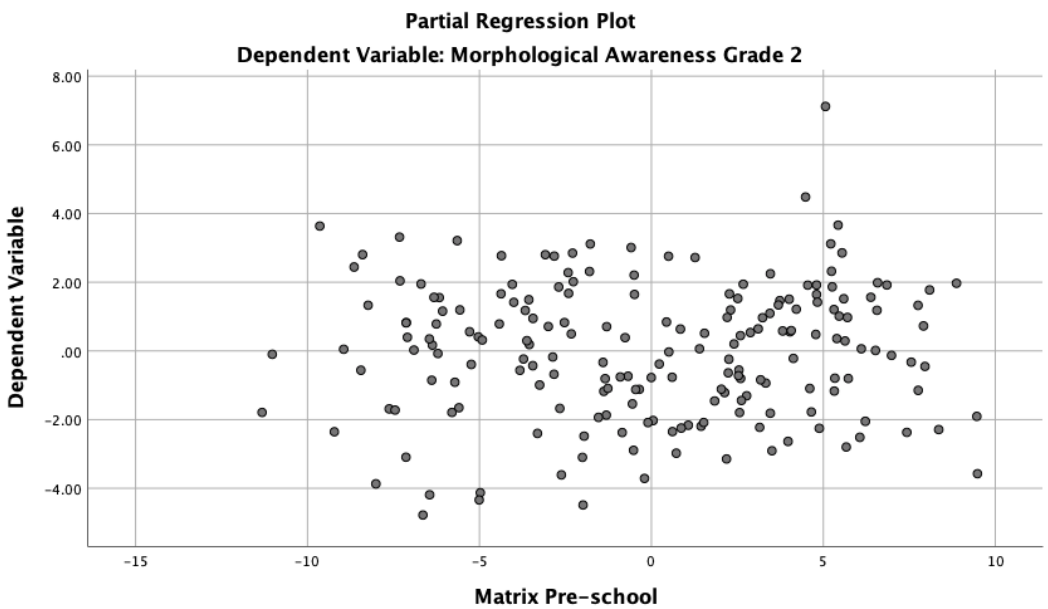

Figure 35. *Partial Regression Plot Grade 2 Outcome: Matrix*

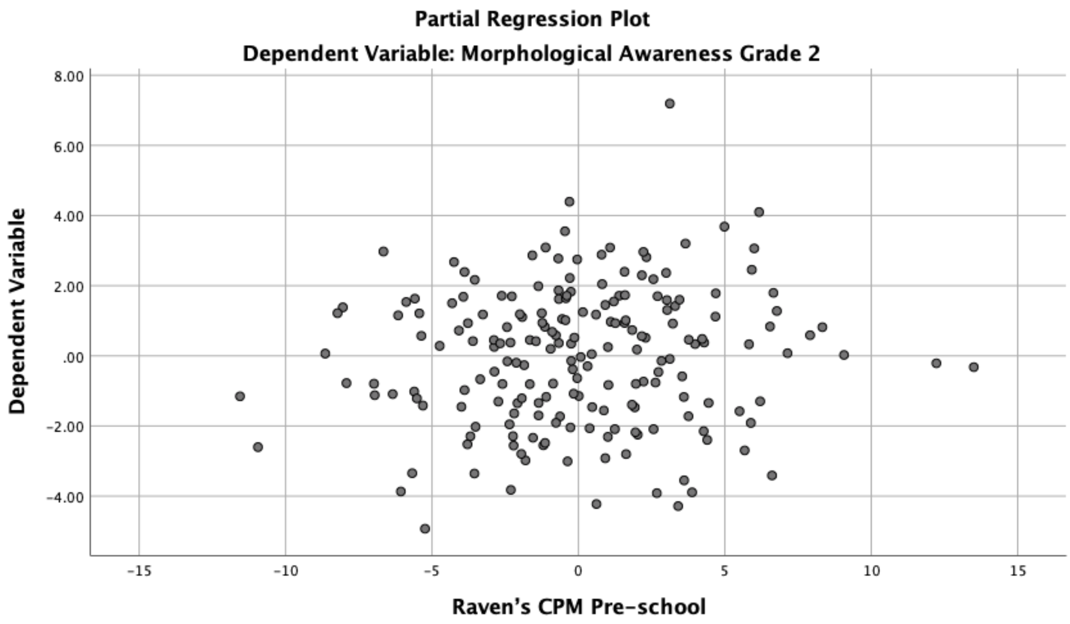

Figure 36. *Partial Regression Plot Grade 2 Outcome: Raven's CPM*

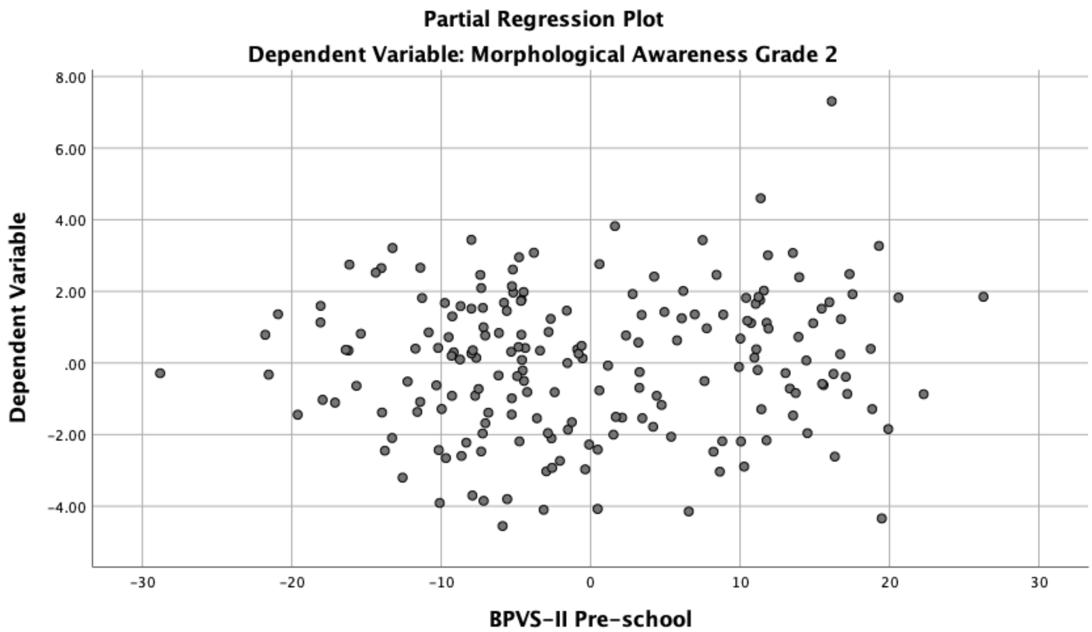

Figure 37. *Partial Regression Plot Grade 2 Outcome: BPVS-II*

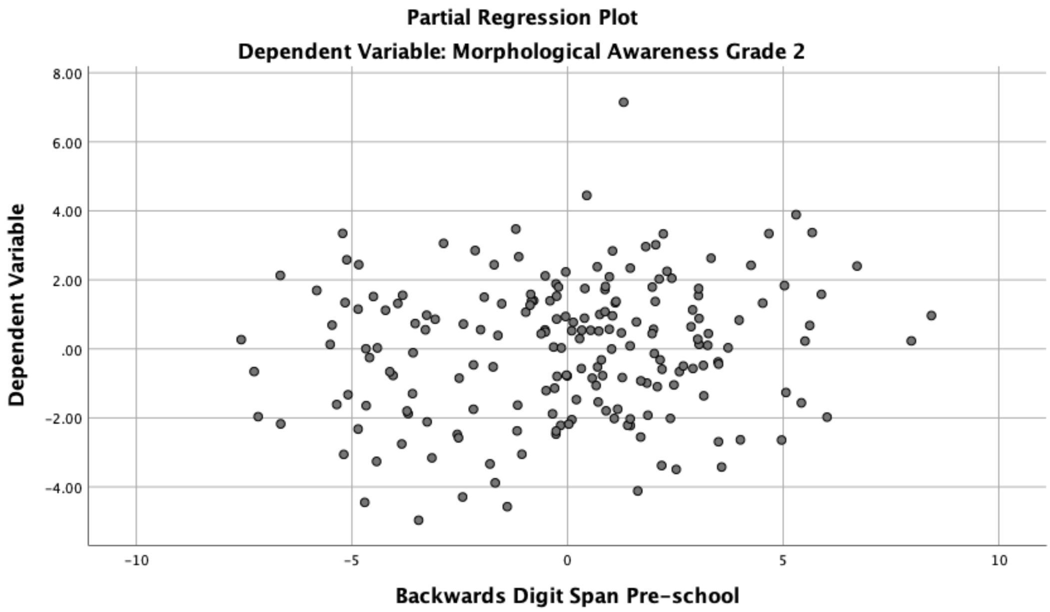

Figure 38. *Partial Regression Plot Grade 2 Outcome: Backward Digit Recall*

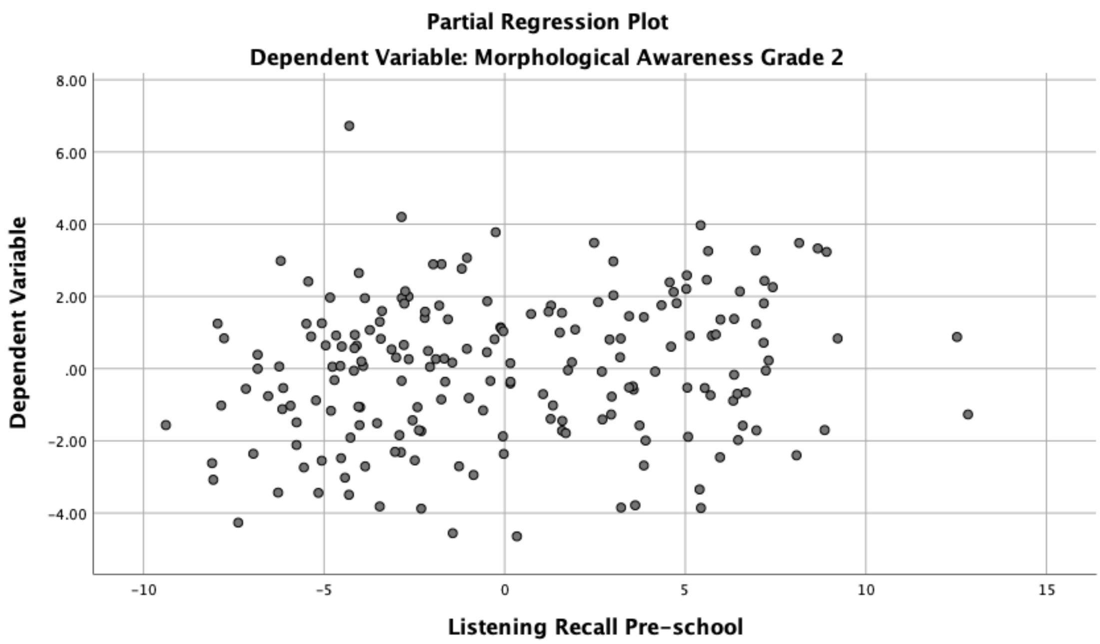

Figure 39. *Partial Regression Plot Grade 2 Outcome: Listening Recall*

Appendix 4: ANOVA-Outputs Grade 1 and Grade 2

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	490.485	1	490.485	79.618	.000[b]
	Residual	1188.964	193	6.160		
	Total	1679.449	194			
2	Regression	506.657	2	253.329	41.473	.000[c]
	Residual	1172.791	192	6.108		
	Total	1679.449	194			
3	Regression	513.137	4	128.284	20.898	.000[d]
	Residual	1166.312	190	6.138		
	Total	1679.449	194			
4	Regression	524.942	6	87.490	14.247	.000[e]
	Residual	1154.507	188	6.141		
	Total	1679.449	194			

a. Dependent Variable: MA_G1

b. Predictors: (Constant), MA_K

c. Predictors: (Constant), MA_K, BPVS_K

d. Predictors: (Constant), MA_K, BPVS_K, Matrix_K, RavenCPM_K

e. Predictors: (Constant), MA_K, BPVS_K, Matrix_K, RavenCPM_K, ListenRec_K, DigSpanB_K

Table 6. *ANOVA-Output from SPSS Grade 1*

ANOVA[a]

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	406.671	1	406.671	79.787	.000[b]
	Residual	983.709	193	5.097		
	Total	1390.379	194			
2	Regression	419.496	2	209.748	41.479	.000[c]
	Residual	970.884	192	5.057		
	Total	1390.379	194			
3	Regression	427.348	4	106.837	21.078	.000[d]
	Residual	963.032	190	5.069		
	Total	1390.379	194			
4	Regression	481.757	6	80.293	16.613	.000[e]
	Residual	908.623	188	4.833		
	Total	1390.379	194			

a. Dependent Variable: MA_G2

b. Predictors: (Constant), MA_K

c. Predictors: (Constant), MA_K, BPVS_K

d. Predictors: (Constant), MA_K, BPVS_K, Matrix_K, RavenCPM_K

e. Predictors: (Constant), MA_K, BPVS_K, Matrix_K, RavenCPM_K, ListenRec_K, DigSpanB_K

Table 7. *ANOVA-Output from SPSS Grade 2*