The Contributions of Language and Literacy Skills to Mathematical Performance in Children Learning English as an Additional Language

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Abstract

In recent years, research has demonstrated that children learning English as an Additional Language (EAL) show a weakness in reading comprehension, and its underlying language comprehension skills, relative to children whose first language is English (FLE). Despite this, relatively little attention has been paid to how this disadvantage might affect performance in other areas of education, such as mathematics. Indeed, national performance data from England shows a mathematical achievement gap between EAL and FLE children. A growing body of research has suggested that EAL children struggle with mathematical word problem solving relative to their FLE peers, given its reliance on reading comprehension. However, research seeking to clarify the relationships between linguistic abilities and mathematical performance in EAL and FLE children within the UK context is scarce. The current study compares the linguistic and mathematical abilities of EAL and FLE children in Key Stage 2 and investigates the linguistic and cognitive predictors of reading comprehension, arithmetic computation and mathematical word problem solving ability in both groups. A sample of 28 EAL and 44 FLE children from Year 3 and Year 5 were assessed on a battery of measures, and a sub-sample were reassessed one year later. In comparison to their FLE peers, the EAL children showed weaknesses in language comprehension and struggled with the contextualisation of arithmetic problems into mathematical word problems, but displayed comparable decoding and arithmetic skills. Overall, the predictors of reading comprehension and mathematical performance were comparable between the language groups, though general vocabulary knowledge was found to be a stronger predictor of both reading comprehension and mathematical word problem solving for the EAL children. The relevance of these findings to our understanding of academic achievement in EAL children are discussed, as well as their educational implications.

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Author’s Declaration

I declare that this thesis is a presentation of original work and I am the sole author. This work has not previously been presented for an award at this, or any other, University. All sources are acknowledged as References.

Introduction

In recent years, the demographic characteristics of children in typical English classrooms have been steadily changing as a result of increased rates of net international migration to the UK. The number of children enrolled in English schools who are categorised as having English as an Additional Language (EAL) has increased substantially over recent years (Strand, Malmberg & Hall, 2015), making classrooms more linguistically diverse than ever. In January 2021, 19.3% of all children in UK schools were recorded as EAL learners (Department for Education [DfE], 2021). Evidence suggests that EAL children often fall behind their monolingual peers academically despite the growing numbers of EAL children in the UK and the rising provision for them available in schools. For example, Strand and colleagues highlighted an achievement gap between EAL children and children whose first language (L1) is English (FLE) throughout primary and secondary school. This achievement gap narrows with age but is especially problematic during the primary school years. It is important to investigate this achievement gap further, given that academic achievement is linked to many positive outcomes such as higher levels of well-being, academic self-concept and socioeconomic success later in life (Guay, Marsh & Boivin, 2003; Quinn & Duckworth, 2007; Strenze, 2007), with the aim to help EAL children overcome any effects of their language barrier and enable them to perform to their full potential.

The majority of the existing research into the academic performance of EAL children has investigated how they compare to FLE children on measures related to language proficiency and literacy. This is understandable, given that EAL children are typically taught in a language different to the one they use at home with their families and that literacy skills are essential to success in many different aspects of education. Typically, EAL children have been found to struggle with language comprehension and reading comprehension in comparison to their FLE peers (e.g., Hutchinson, Whiteley, Smith & Connors, 2003; Melby-Lervåg & Lervåg, 2014). There has, however, been relatively little research into how the linguistic disadvantage that EAL children face affects their performance in other academic domains. Recently, researchers have started to investigate how EAL learners perform in mathematics, an area in which they do underperform compared to FLE learners but to a lesser extent than in literacy (Strand et al., 2015). At first glance, the domain of mathematics appears to be largely distinct from language. In fact, mathematics is often referred to as the “universal language”, but evidence from research has shown that this is not the case in practice. In reality, various aspects of the way in which mathematics is both taught and assessed rely heavily on language ability and differ between languages. For example, learning mathematics requires individuals to learn and understand mathematical vocabulary, which consists not only of unique words specific to the subject but also words which have a different meaning in mathematics than they do in everyday life, such as *product* (Dale & Cuevas, 1987). Furthermore, scores on a range of language skills have been found to predict performance on different mathematical tasks (e.g., Bjork & Bowyer-Crane, 2013; Fuchs et al., 2006; Grimm, 2008; Purpura, Hume, Sims & Lonigan, 2011), suggesting that language and mathematics are not as distinct from each other as is often believed.

Although the link between language and mathematics has become recognised in the literature, very little research has applied this to EAL children and considered how their particular linguistic profile translates to their performance on different mathematical tasks in comparison to FLE children and the factors which predict their performance on these tasks. Given the established link between language and mathematics and the existence of an achievement gap in mathematical performance between EAL and FLE children, it is important to identify the particular areas of mathematics that EAL children are likely to struggle with and the reasons for this, so that these can be addressed in practice. This thesis will therefore seek to confirm the linguistic profile of EAL children, before assessing and comparing performance on different mathematical tasks in EAL and FLE children and the linguistic and cognitive skills which underpin this for each group.

The current study employed a cross-sequential design in order to examine the linguistic and mathematical abilities of both EAL and FLE children across the course of Key Stage 2 (KS2). A group of Year 3 children and a group of Year 5 children, each consisting of both EAL and FLE learners, completed an extensive battery of linguistic, cognitive and mathematical measures including reading comprehension and its subcomponents, phonological skills, mathematical vocabulary knowledge, arithmetic computation and mathematical word problem solving (WPS). A subset of the children then also completed a reduced battery of measures a year later. The linguistic and mathematical abilities of the EAL and FLE children were compared both cross-sectionally and longitudinally. In addition, the concurrent and longitudinal predictors of reading comprehension, arithmetic computation and mathematical WPS were examined in both language groups.

Thesis Outline

Chapters 1 and 2 of this thesis review the literature surrounding the linguistic and mathematical abilities of EAL and FLE children. Chapter 1 focuses on reading comprehension and its subcomponents, and is split into three main sections. The first section explores bilingualism and the EAL population in England, after which the second section reviews evidence from the literature regarding reading comprehension and its subcomponents in EAL and FLE children, within the framework of a leading model of reading comprehension. The third section reviews the literature surrounding the key predictors of reading comprehension in EAL and FLE children. Chapter 2 focuses on mathematical performance, exploring firstly the role of language in mathematics, before reviewing literature which has compared the mathematical performance of EAL and FLE children and finally the literature surrounding the key predictors of mathematical WPS. Chapter 3 details the methodology of the current study and presents the results of a pilot study assessing the suitability of several bespoke measures designed for use in the main study. Chapters 4, 5 and 6 present and discuss the results of the main study. Specifically, Chapter 4 analyses the Time 1 (T1) data in order to compare the linguistic abilities of EAL and FLE children and the predictors of reading comprehension in both language groups, while Chapter 5 presents the results of similar analyses using the T1 mathematical measures. Chapter 6 analyses the longitudinal data collected at Time 2 (T2), examining the developmental trajectories of linguistic and mathematical abilities in EAL and FLE and assessing the longitudinal predictors of reading comprehension, arithmetic computation and mathematical WPS in both language groups. Finally, Chapter 7 summarises and discusses the findings of Chapters 4, 5 and 6, before reviewing the strengths and limitations of the current study, possible directions for future research and the educational implications of the findings presented in this thesis.

1 Reading Comprehension in EAL and FLE Children

1.1 Bilingualism

Although often regarded as a simple classification, the concept of bilingualism is one of considerable complexity and nuance. Put simply, bilingualism can be defined as “knowing two languages” (Valdés & Figueroa, 1994). However, researchers have long debated what it means to “know” a language in the context of bilingualism; for example, Bloomfield (1933) stated that individuals must have full native-like fluency in two languages to be deemed bilingual, while more recently, researchers such as Grosjean (1989, 2013) have argued that it is necessary only to be able to function sufficiently in each language to fulfil one’s own needs in order to be termed bilingual. Indeed, “true bilingualism” (i.e., native-like proficiency in two languages) is very rare in bilingual individuals (e.g., Cutler, Mehler, Norris & Segui, 1992; Grosjean, 2013) and in fact not all bilingual individuals possess equal levels of proficiency in both languages; many bilingual individuals have a dominant language which might have been established through preference, proficiency or context.

In recent years, the concept of bilingualism has expanded to see past the single deciding criterion of fluency in each language. While still acknowledging that fluency level is an important factor, researchers such as Mackey (1962) first recommended the consideration of language function as another factor. This refers to how often the individual uses each language in everyday life, and the contexts in which each language is used. Bilingual individuals might be exposed to each language to varying extents across different contexts such as in the home, in places of education, at work, in the community or in the media, resulting in each language having a context-bound function. Definitions of bilingualism are also influenced by other factors such as the age of acquisition of each language and the context of language learning as well as of language use (Gottardo & Grant, 2008). In order to take this into account, a distinction is often made within the literature between “simultaneous bilinguals”, which refers to those who learn two languages concurrently from birth or infancy, and “sequential bilinguals” who begin to acquire a second language (L2) after infancy (Kohnert, 2010). A further complexity within bilingualism is variation in the proficiency of bilingual individuals across the subskills of each language (Gottardo & Grant, 2008). It is possible for an individual to, for example, have the ability to understand and speak two languages with equal proficiency, but have limited reading and writing proficiency in one language. Furthermore, these nuances are dynamic, meaning that a bilingual individual’s proficiencies and language dominance across the subskills of each language can wax and wane over time (e.g., Grosjean, 2013).

The discussed complexities within bilingualism demonstrate the difficulty in categorising individuals as bilingual in a binary way. Some have suggested that bilingualism should not be treated categorically, but instead as a continuum accounting for such complexities (e.g., Gottardo & Grant, 2008; Kaushanskaya & Prior, 2015; Luk & Bialystok, 2013). As such, it is recommended that researchers should both consider and measure the different dimensions of bilingualism such as proficiency in both languages of their participants as well as their typical frequency and context of language use. While such practices are recommended for research into bilingualism, in reality many studies continue to treat bilingualism as a dichotomous variable for several reasons. For example, educational researchers are often confined to using the binary classification rules used by the education system in the country of interest. In England, school children are categorised as either monolingual or EAL learners. The study presented in this thesis observes this classification system, but also strives to take into consideration the context and complex dimensions of bilingualism by gathering data exploring the nuances and contexts of bilingualism in each EAL participant and their home environments.

1.1.1 EAL Learners in England

The definition of EAL status laid out by the DfE, much as the common definition of bilingualism mentioned in the previous section, is considerably vague and all-encompassing. According to the definition laid out by the DfE, children in the English school system should be classified by their school as EAL learners if they are "exposed to a language at home that is known or believed to be other than English" (DfE, 2019b, p. 9). Over the recent years, the number of children in English schools categorised as EAL has been steadily increasing, with Demie, McDonald and Hau (2016) reporting that between 1997 and 2014 alone, the overall percentage of EAL children enrolled in English schools rose from 7.6% to 16.6%; an increase of 118%. Government statistics show that in January 2021, the proportion of children labelled as EAL learners stood at 20.9% in English primary schools, and 17.2% in English secondary schools (DfE, 2021). While the overall national proportion of EAL children in English schools stands at around 20%, EAL children are not distributed evenly between schools or indeed between geographical regions. The percentage of EAL children enrolled in English schools varies greatly; according to Strand and colleagues (2015), EAL children comprise less than 5% of the pupil population in just over half of all English schools, and less than 1% of the pupil population in around one in five English schools. Conversely, Strand and colleagues state that 8.4% of English schools have an EAL majority. Of these schools, most are situated in London, the West Midlands, Yorkshire and the Humber and the North East. Indeed, these areas have also been shown to contain the highest concentrations of EAL children overall (e.g., Hutchinson, 2018).

While the DfE definition of EAL status specifies that the use of a language other than English should occur in the home, it does not provide further criteria pertaining to dimensions of bilingualism such as language proficiency. Furthermore, it does not recognise a distinction between simultaneous and sequential bilinguals, meaning that children who speak another language in the home are categorised as EAL regardless of when they began to learn each language. A common misconception is that EAL children are by definition sequential bilinguals, having started to learn English on starting primary school or nursery, however it is entirely possible under the DfE definition that an EAL child started to learn both English and another language from birth. Furthermore, while EAL children might start school with their home language being dominant, persistent exposure to English at school might quickly lead to English taking dominance over their home language. The all-encompassing nature of the DfE definition of EAL status means that children are categorised as EAL based solely on exposure to another language in the home, resulting in a very heterogeneous EAL population displaying wide variation on a host of important factors.

One factor which is unaccounted for when categorising children as EAL is their level of Proficiency in English (PiE). In fact, the DfE definition itself alludes to this, stating that "This measure is not a measure of English language proficiency or a good proxy for recent immigration" (DfE, 2019b, p. 9), thus making it clear that assigning a child EAL status does not imply anything about their level of PiE. Indeed, the fact that a child is being exposed to another language in the home indicates neither their level of PiE nor any information about related factors such as the extent of their prior exposure to the English language. Thus, the EAL population includes individuals who range in PiE from those who may have recently arrived in the UK and have had very little prior English exposure or have very rarely spoken English in the home to those who grew up in the UK and are very competent, if not fluent, and frequent English speakers. Given that factors such as PiE are likely fundamental to the academic performance of EAL children being taught in English, a more nuanced EAL classification system would allow the EAL children who are most in need of support to be targeted.

Despite the palpable importance of PiE to the academic achievement of EAL children, schools in England are not currently required to assess or provide any information on the English proficiency levels of their EAL pupils; the only information that must be made available by schools regarding their pupils' language status is the binary indication of whether English is spoken in the home of each child or not. Hutchinson (2018) discusses the importance of schools assessing the English proficiency of their EAL learners and gives examples of how this is implemented in other English-speaking countries such as Australia and the USA. In fact, as later mentioned by Hutchinson, a promising new DfE requirement for schools to assess the PiE of their EAL pupils and place them into one of five proficiency levels: "New to English", "Early Acquisition", "Developing Competence", "Competent" or "Fluent" (DfE, 2017, pp. 13-14) was introduced in January 2017. This requirement was, however, removed after the school census of January 2018, following concerns that such data was to be used for purposes of immigration enforcement, and no such proficiency scales have since been re-introduced. Despite their abrupt withdrawal, there is evidence from the brief implementation of the proficiency scales that the EAL population of England range greatly in their PiE levels. Evidence published by the DfE (2017) demonstrates the wide variation in PiE amongst EAL children in England, and that approximately one in three EAL children are in fact fluent in English despite the presence of another language in the home; in January 2017, 5.3% of the EAL population were New to English (Stage A), 10.5% were in the Early Acquisition stage

(Stage B), 19.4% were Developing Competence (Stage C), 22.8% were Competent (Stage D) and 33.4% were Fluent (Stage E), with the final 8.7% of data missing.

Another contributor to the heterogeneity of the EAL population in England is the extremely wide range of L1s spoken by EAL children. According to a demographic analysis of the EAL population across KS2 in 2016 by Hutchinson (2018), the five most prevalent L1s amongst EAL children in England are Urdu (11.5%), Panjabi (10.5%), Bengali (8.3%), Polish (6.9%) and Arabic (4.6%). However, there were a total of 51 languages spoken by over 200 children altogether, with many more spoken by less than 200 children. This heterogeneity is by no means present in all English-speaking countries; for example, 76.5% of EAL children in the USA have Spanish as their L1 (Goodrich, Lonigan & Alfonso, 2019).

The EAL population in England also varies greatly in terms of when each child joined the English education system. According to Hutchinson (2018), 65% of EAL children in the 2016 KS2 and Key Stage 4 (KS4) cohorts joined an English primary school in Reception. 16% were estimated to have joined the English education system in Year 2, and less than 5% joined in each of the following years (i.e., from Year 3 to Year 11). Overall, it is clear that the EAL population in England is extremely heterogeneous for a number of reasons, and it is likely that this heterogeneity will cause variation in the academic achievement of this population.

1.1.2 The Academic Achievement of EAL Learners in England

National performance data suggests that EAL children perform less well academically than FLE children when being taught in English schools. This achievement gap narrows with age, but is particularly noticeable during the primary school years. In an analysis of data from the National Pupil Database, Strand and colleagues (2015) reported that 10% fewer EAL children than FLE children showed an overall Good Level of Development (GLD) at the age of 5. The achievement gap decreased slightly to stand at 8% at the age of 7, and then further to 5% at the age of 11. Demie (2018a) reported a similar national achievement gap at age 11, stating that 71% of EAL children achieved Level 4 or higher in Reading, Writing and Mathematics, compared to 75% of FLE children. According to Strand and colleagues, only 2% fewer EAL children than FLE children achieve an overall GLD at the age of 16. This is reflected in national GCSE performance data; Demie and colleagues (2016) reported an achievement gap of 2% between EAL and White British children, with 57% of White British children achieving five A*-C grades at GCSE compared to 55% of EAL children. These reports show that an achievement gap between EAL children and FLE children exists, and that EAL children are most at risk of academic disadvantage during their primary school years. Despite this, taken at face value, the national performance data presented previously paint an optimistic picture regarding the academic performance of EAL children; it seems that although an achievement gap is present throughout all school years, this gap is small and narrows over time, suggesting that EAL children will be able to catch up to their monolingual peers more or less. However, it is important to consider that national performance data provides only overall figures and does not account for the idiosyncrasies of the population. Given the high heterogeneity of the EAL population in England and the broad definition of EAL status, it is likely that the academic disadvantage faced by some EAL children is misrepresented in national performance data, making it difficult to draw any real conclusions.

There is evidence to suggest that the academic achievement of EAL children is highly dependent on a number of factors. One of these factors is PiE, which is highly variable within the EAL population in England (as discussed in Section 1.1.1). National data regarding the link between PiE and academic achievement was not published by the government before the withdrawal of the proficiency scales. However, several studies gathered proficiency scales data from subsets of the population and found PiE to be a strong predictor of academic achievement in EAL children. Demie (2018b) found that in a London local authority, academic achievement increased with PiE in KS2 and GCSE students, particularly in literacy. An analysis of the proficiency scales data from schools in six local authorities around England by Strand and Hessel (2018) found a strong link between PiE and academic achievement across Reception, Key Stage 1 (KS1), KS2 and KS4, with children in PiE Stages A and B typically performing below the national average and children in Stages D and E actually outperforming FLE children. Strand and Hessel also found that PiE uniquely accounted for up to 22% of the variance in academic performance across the age groups, while gender, Free School Meals (FSM) eligibility and ethnicity together typically accounted for only 3-4% of the variance. Furthermore, Strand and Hessel found that PiE ratings vary strongly with age, with the proportion of EAL children in Stages A to C standing at 70.6% in Reception, 48.7% at the end of KS1, 23.2% at the end of KS2 and 15.3% at the end of KS4. This suggests that PiE is likely to be the reason for the narrowing of the achievement gap over time. Hessel and Strand (2021) found PiE to be a significantly better predictor of EAL academic achievement than EAL status alone. Similar results were found in a study analysing PiE data from primary schools in Wales where schools are required to assess the PiE of their EAL children using the proficiency scales (Strand & Lindorff, 2020, 2021), and a study analysing PiE data from the local authority of Lambeth, which has long collected PiE data using a similar scale (Demie, 2018a). For example, Strand and Lindorff (2020) followed a cohort of children from Reception to Year 6, finding that EAL children starting at Stage A typically take 6 years to reach competency in English and that time taken to progress through the stages is also significantly related to academic achievement. From this evidence, it is clear that PiE is strongly linked to academic performance in EAL children, and that the reintroduction of the proficiency scales in England would allow academic achievement in EAL children to be analysed with more nuance.

Another factor which has been linked to academic achievement is the L1 of EAL learners. Demie and colleagues (2016) suggest that EAL children in England with certain L1s are more at risk for difficulties in school than others. They present data showing that although the national average for achievement of five or more A*-C GCSE grades including mathematics and English in EAL children is 57%, the range for this figure spans from 85.4% for those with Japanese as their L1 to 10.4% for those with Czech as their L1. Hutchinson (2018) also highlights the large discrepancies in EAL achievement based on the L1 of the children. According to Hutchinson, EAL children with Czech, Slovak, Portuguese, Turkish, Panjabi or Pashto as their L1 score below the national average level of attainment even if they arrived in the UK during infancy. In contrast, EAL children with Chinese, Hindi or Tamil as their L1 achieve above the national average even if they arrived in the UK as late as Year 5. One possible explanation for this disparity is variation in socioeconomic status (SES) and migration history between families of different ethnicities and nationalities. While evidence suggests that SES affects the academic development of monolingual and bilingual children similarly (Calvo & Bialystok, 2014; Chiat & Polišenská, 2016; Meir & Armon-Lotem, 2017), demographic statistics show that FSM eligibility varies greatly between EAL children based on their L1 and is typically higher for EAL children than monolingual children. For example, Strand, Malmberg and Hall (2015) reported that while 11% of monolingual English children in England were eligible for FSM, this figure stood at 19% for Portuguese-speaking EAL children, at 31% for Slovak-speaking EAL children and at 39% for Turkish-speaking EAL children. There is also evidence that Black African, Pakistani and Bangladeshi EAL children in England are much more likely to be eligible for FSM than White British children, while Chinese and Indian EAL children in England have lower levels of FSM eligibility than White British children (Gorard, 2012). Taking these figures into account, it seems that SES might explain the disparity between the academic achievement of EAL children with L1s such as Czech, Slovak, Portuguese, Turkish, Panjabi or Pashto and those with L1s such as Chinese, Hindi or Tamil.

Indeed, a study by Strand and colleagues (2010) found underattainment in EAL children to be significantly predicted by SES. Specifically, Strand and colleagues investigated the attainment of Somali, Bangladeshi and Turkish EAL children in England. All three groups had high proportions of FSM eligibility; this stood at 82% in the Somali group, 52% in the Bangladeshi group and 41% in the Turkish group. Strand and colleagues also noted that the Bangladeshi group had improved the most in terms of academic achievement over previous years, and highlighted that while most of the Turkish and Somali EAL children were children of first-generation migrants, often refugees or asylum seekers, the majority of the Bangladeshi children were children of second-generation migrants who typically had better levels of PiE and greater familiarity with the English education system. This suggests that migration history can also explain differences in academic achievement in EAL children, and that this might be due to variation in the ability of parents to support their children academically and engage with schools effectively.

Another possible reason for the wide variation in academic achievement based on the L1 of EAL children is the typological distance between English and each L1; this refers to how structurally similar the two languages are. It is possible that EAL children with L1s which are typologically further from English might perform less well academically, due to a reduced ability to transfer grammatical knowledge across their languages (e.g. Chung, Chen & Geva, 2019). The role of typological distance in additional language learning has been demonstrated in the literature; for example, Schepens, van der Slik and van Hout (2016) found that 48% of the variation in L3 proficiency in Dutch in a multilingual sample could be explained by the typological distance between participants' L1 and Dutch, while 32% of the variation could be explained by the typological distance between each L2 and Dutch. However, evidence suggests that languages such as Chinese, Hindi and Pashto are further from English typologically than languages such as Portuguese, Turkish and Czech (Chiswick & Miller, 2005), which suggests that typological distance did not play a strong role in the academic differences reported between EAL speakers of these languages by Hutchinson (2018), or that its role was perhaps eclipsed by that of SES. Given that no analysis of the effect of typological distance on the academic achievement of EAL children in England has been carried out in the literature, future research should aim to investigate this alongside the role of SES. Overall, the academic achievement of EAL children in England seems to depend somewhat on the L1 of each child. This might be linked to factors such as SES or typological distance, and is important to consider when carrying out research with EAL children.

Finally, Hutchinson (2018) also reports data suggesting a correlation between when EAL individuals joined the English education system and their academic performance, with those arriving in Reception, Year 1 or Year 2 scoring at or above the expected standard for reading and mathematics at the end of KS2 and those arriving in Year 3, Year 4 or Year 5 scoring well below the expected standard. This variation in arrival time also means that some EAL children will have missed certain assessment points entirely and will therefore be further misrepresented in national data. In fact, according to Hutchinson, roughly 30% of EAL children in UK primary schools are estimated to have missing data for one or more assessment points within the English education system.

Based on the discussed evidence, it becomes clear that some EAL children are misrepresented by national performance data. It is likely that the disadvantage faced by the EAL children who are most at risk is masked by the inclusion of many children in the EAL population who are extremely proficient at English or otherwise less at risk of disadvantage, and is thus being underestimated. The academic disadvantage faced by EAL children should not be overlooked based on evidence suggesting that EAL children catch up academically with their FLE peers by the end of their compulsory education; not only is it important to tackle academic disadvantage at every stage of education (e.g. Frawley, 2014), but it is likely that some EAL children do not catch up academically due to difficulties with the English language and that this is being masked in national performance data.

Given the discussed issues around the interpretation of the national performance data of EAL children and the fact that schools in England are not currently required to record information such as the PiE levels of their EAL pupils, empirical research which is able to look beyond the umbrella term of "EAL" to identify which children are most in need of support is a valuable instrument in the investigation of the academic achievement of EAL children. However, there is a distinct scarcity of UK-based research investigating the predictors of academic achievement in EAL children and, in particular, possible methods of intervention to support them academically (Murphy & Unthiah, 2015; Oxley & de Cat, 2021). This can make it difficult for teachers to know how best to support the learning of EAL children, especially in areas of the country where EAL numbers are relatively low (Bailey & Marsden, 2017). This lack of research is particularly noticeable when considering the performance of EAL children in academic subjects other than literacy, such as mathematics. Given the rising numbers of EAL children in England and their potential academic disadvantage, continued research aiming to identify the predictors of academic performance in EAL children and to shed light on how to support those most at risk is essential. This thesis addresses this need through examination of the linguistic and cognitive predictors of both reading comprehension and mathematical performance in EAL children and of where amongst these EAL children's weaknesses typically lie.

1.1.3 Terminology Adopted in this Thesis

As discussed above, the term "EAL" is used in this thesis to refer to children being taught in English who are exposed to a language other than English in their home environment (although not necessarily exclusively) and thus have English as an additional language, based on the definition laid out by the DfE in England. This thesis uses the terms EAL children and EAL learners interchangeably to refer to members of this population. Although the term EAL has been adopted nation-wide in the UK, other countries use different terms to describe EAL learners and thus this literature review discusses studies in which terms other than EAL are used. For example, research from the USA and Canada tends to describe such individuals as "English Language Learners", having moved away from the term "Limited English Proficiency" due to concerns that it puts blame on the individuals for their lower PiE levels (Cunningham, 2019). In the interest of clarity, this thesis exclusively uses the term EAL to refer to the population in question, including during discussions of papers in which the authors used an alternative term. Other terms found in the literature to describe bilingual individuals are language-minority learner, second-language learner and emergent bilingual. These terms do not specify English as the second or additional language and accordingly, "language-minority learners" and "language-minority children" will be used interchangeably to describe bilingual populations for which the additional language is a language other than English for some or all individuals.

This thesis uses the terms FLE children and FLE learners interchangeably to refer to children who have English as their L1, are being taught in English and have no exposure to another language in the home. These children are often referred to simply as monolingual in the literature, however this term does not specify that their only language is English; for this reason, the unambiguous term FLE was chosen to be used in this thesis. However, when discussing international research, populations whose only language is a language other than English for some or all individuals will be referred to simply as monolingual.

1.2 Reading Comprehension

When considering the academic profile of EAL children, the most foreseeable and immediate academic disadvantage they are likely to face is in literacy. Indeed, national data presented by Strand and colleagues (2015) showed that the largest achievement gap between EAL and FLE children between the ages of 5 and 16 was consistently in reading and that reading is the subject in which the achievement gap between EAL and FLE children narrows the least as their education progresses. Between the ages of 5 and 11, 8-10% fewer EAL children than FLE children achieved at the least expected level in reading, and at the age of 16, 4% fewer EAL children than FLE children achieved an A*-C grade at GCSE English. It is important to remember that national performance data is not sensitive to factors such as PiE and is likely to misrepresent many EAL children, meaning that the gap is likely to be even wider for those with lower levels of PiE. Indeed, reports such as that by Strand and Hessel (2018) have shown EAL reading or literacy performance in Key Stages 1, 2 and 4 to increase significantly with levels of PiE, to a greater extent than in other subject areas. It is clear from this evidence that EAL children typically struggle with reading skills, particularly those with limited PiE. Given that reading skills are vitally important to academic performance across all disciplines, research investigating how best to support EAL children who struggle with reading, such as the study presented in this thesis, is crucial.

Reading comprehension can be defined as the ability to create meaning from written text (van Dijk & Kintsch, 1983). Put simply, reading comprehension is the over-arching goal of learning to read, involving not only the ability to read and understand individual words but also the ability to comprehend sentences and passages of text and to integrate their meaning with one's prior knowledge. Thus, reading comprehension is a multi-dimensional and complex skill which is key to language learning. This section will explore the literature surrounding the reading comprehension profiles of EAL children in comparison to FLE children, as well as a theoretical model of reading comprehension and its applicability to EAL children.

1.2.1 Reading Comprehension in EAL Children

Difficulty with reading comprehension in English is thought to be the main disadvantage faced by EAL children and has been a clear focus of the surrounding literature (Murphy & Unthiah, 2015). A number of studies have documented gaps in performance on reading comprehension tasks between EAL and FLE children in the UK. For example, Hutchinson and colleagues (2003) followed a group of EAL and FLE children from Year 2 to Year 4, and found that the FLE children scored significantly higher on a measure of reading comprehension than the EAL children ($\eta^2 = .17$), outperforming the EAL children at each of the three time points. The authors demonstrated that although both groups made similar progress in reading comprehension over the 2 years, the reading comprehension abilities of the EAL children consistently lagged approximately 1 year behind those of the FLE children.

Other UK-based research has also shown FLE children to outperform EAL children on measures of reading comprehension across a range of ages (e.g., Babayiğit, 2015; Beech & Keys, 1997; Burgoyne, Kelly, Whiteley & Spooner, 2009; Burgoyne, Whiteley & Hutchinson, 2011, 2013; Rosowsky, 2001; Trakulphadetkrai, Courtney, Clenton, Treffers-Daller & Tsakalaki, 2017). Burgoyne and colleagues (2009) found a significant difference in reading comprehension scores between Year 3 EAL and FLE children ($\eta^2 = .15$). A longitudinal study by Burgoyne and colleagues (2011) carried out over the course of Year 3 and Year 4 initially found no significant difference in reading comprehension scores between EAL and FLE children. However, the authors explain that administration of the reading comprehension measure used in the study was halted based on the number of reading errors made, and that on controlling for reading accuracy, the difference in reading comprehension scores between the EAL group and the FLE group became statistically significant. EAL deficits in reading comprehension have also been shown to be present in Year 5 children (Babayiğit, 2015; Trakulphadetkrai et al., 2017) and Year 7 children (Rosowsky, 2001). Overall, evidence from research carried out in the UK shows a clear EAL disadvantage on measures of reading comprehension in comparison to FLE children.

There is further evidence from international research that shows the difficulty that language-minority learners face with reading comprehension. In a systematic meta-analysis investigating the performance of language-minority and monolingual children on reading comprehension and its predictors, Melby-Lervåg and Lervåg (2014) reported a substantial difference in reading comprehension scores between the groups, with a medium effect size of $d = -0.62$ across 82 studies carried out in a wide range of countries. Many international empirical studies have echoed the findings of studies carried out in the UK by showing language-minority children to score significantly lower than monolingual children on measures of reading comprehension across a range of ages (e.g., Droop & Verhoeven, 2003; Geva & Farnia, 2012; Kieffer & Vukovic, 2012; Lervåg & Aukrust, 2010; Nakamoto, Lindsey & Manis, 2007; Raudszus, Segers & Verhoeven, 2018; Verhoeven & van Leeuwe, 2012). Group differences in reading comprehension have often been observed in children aged approximately 8 to 10 years old; for example, Droop and Verhoeven found monolingual Dutch-speaking children to consistently outperform both Turkish and Moroccan language-minority learners of Dutch longitudinally between the ages of 8 and 10. Lervåg and Aukrust found similar results when comparing 7-year-old monolingual speakers of Norwegian and language-minority learners of Norwegian with Urdu as their L1 at four time points over the course of 18 months, noting that the monolingual group also made larger gains in reading comprehension than the language-minority group. There is also evidence from international research that the gap in reading comprehension ability narrows over time; for example, Verhoeven and van Leeuwe found consistently significant but increasingly smaller reading comprehension deficits in a group of language-minority children when compared to monolingual children across

Grades 2, 4 and 6 (i.e., ages 7-12). Furthermore, a longitudinal study by Lesaux, Rupp and Siegel (2007) found that despite a group of EAL children showing deficits in literacy skills in kindergarten, no difference in reading comprehension scores between the language groups was observed in Grade 4 (i.e., age 9-10). Overall, evidence from international research reflects the evidence from research carried out in the UK, showing that language-minority children exhibit lower levels of reading comprehension than monolingual children, and that the difference between the language groups narrows over time. It is, however, important to remember that the findings of international research cannot always be easily applied to the UK context, due to the wide range of languages spoken by the participants as well as differences in the demographics of the language-minority populations in different countries.

When investigating the L2 reading comprehension of EAL or language-minority children, a factor which is often overlooked in research is their L1 reading comprehension ability. The extent to which reading ability in one language might overlap with and contribute to reading ability in another language is certainly a pertinent question in such research, and has been investigated in a growing body of research. Such research has stemmed from the Developmental Interdependence Hypothesis proposed by Cummins (1979); this hypothesis theorises that L1 proficiency in certain cognitive functions at the time that L2 learning begins predicts the development of L2 proficiency in the same functions, due to a transfer of skills across the two languages. In psychological research, cross-language transfer is most often quantified by a statistical correlation or linear regression between a skill in the L1 and the same skill in the L2 (Sadeghi & Everatt, 2015). There is some evidence that reading comprehension ability does indeed transfer from the L1 to the L2 in language-minority learners (e.g., Asfaha, Beckman, Kurvers & Kroon, 2009; Carrell, 1991; Gebauer, Zaunbauer & Möller, 2013), though research into cross-language transfer primarily focuses on the underlying components of reading comprehension rather than on reading comprehension itself. Therefore, cross-language transfer will be discussed in greater detail later, after the following introduction to a leading model of reading comprehension which has been highly influential in guiding much of the research into EAL literacy and indeed the current study.

1.2.2 The Simple View of Reading

The Simple View of Reading (SVR) model, posited by Gough and Tunmer (1986), states that successful reading ability is the product of two broad components: decoding and language comprehension. These two components each consist of multiple related underlying skills; hence, the model accounts for the complex nature of reading comprehension while also recognising the two over-arching domains into which these skills fall. Gough and Tunmer define decoding as the ability to recognise words accurately, quickly and silently, acknowledging the role of understanding letter-sound correspondence rules within this. As such, they suggest that decoding in the absence of language comprehension is akin to the ability to reason out the pronunciation of pseudowords, which resemble real words but have no semantic meaning. The language comprehension aspect of the model is defined by the authors as the interpretation of lexical information, sentences and discourse; that is, the ability to apply meaning to the words and sentences being read. The authors argue that decoding and language comprehension are both equally important and equally necessary to successful reading; word recognition is not enough to allow an individual to infer any meaning from a text, and neither is successful reading possible in an individual who can fully comprehend a language orally but has no ability to decode sounds and words. This means that full reading comprehension can only occur when in individual possesses both decoding and language comprehension skills, hence the multiplicative structure of the model.

After the initial proposal of the SVR, Hoover and Gough (1990) provided supporting empirical evidence for the model in a longitudinal study measuring reading comprehension and its proposed components in children between kindergarten and Grade 4. Further research has also supported the SVR by demonstrating that decoding and language comprehension both significantly and distinctly predict reading comprehension and together account for a large portion of its total variance (e.g., Catts, Adlof & Weismer, 2006; Dreyer & Katz, 1992; Kendeou, Savage & van den Broek, 2009; Kendeou, van den Broek, White & Lynch, 2009; Lervåg, Hulme & Melby-Lervåg, 2018). Hoover and Tunmer (2018) revisited the SVR, discussing its continued relevance and robustness today and citing two recent papers (Language and Reading Research Consortium & Chiu, 2018; Lonigan, Burgess & Schatschneider, 2018) which provide strong support for the SVR, showing that decoding and language comprehension together account for 85-100% of the variance in reading comprehension ability in children across Grades 3 to 5.

Since its initial conception, the SVR has been shown to be valid in languages other than English, demonstrating its generalisability across languages. Research has supported the SVR in alphabetic languages such as French (e.g., Massonnié, Bianco, Lima & Bressoux, 2019), Italian (e.g., Tobia & Bonifacci, 2015), Greek (e.g., Kendeou, Papadopoulos & Kotzapoulou, 2013; Protopapas, Simos, Sideridis & Mouzaki, 2012), Portuguese (e.g., Cadime et al., 2017; Santos, Cadime, Viana & Ribeiro, 2020), Spanish (e.g., Joshi, Tao, Aaron & Quiroz, 2012), Dutch (e.g., de Jong & van der Leij, 2002; Verhoeven & van Leeuwe, 2012) and Finnish (e.g., Torppa et al., 2016) as well as non-alphabetic languages such as Chinese (e.g., Joshi et al., 2012; Yeung, Ho, Chan & Chung, 2016), Arabic (e.g., Asadi, Khateb & Shany, 2017) and Hebrew (e.g., Joshi, Ji, Breznitz, Amiel & Yulia, 2015). Furthermore, the SVR has been shown to be valid for language-minority individuals; for example, Verhoeven and van Leeuwe found the SVR to be equally valid for language-minority and monolingual learners of Dutch, and similar results were found for language-minority learners of Italian by Bonifacci and Tobia (2017). A study carried out in the USA by Gottardo and Mueller (2009) supports the validity of the SVR for EAL children with Spanish as their L1, finding that oral language proficiency and word reading were the strongest predictors of reading comprehension and together provided the best model for the construct.

While the SVR has been widely supported and has been prominently used in research, several shortcomings of the model have been suggested. Firstly, as discussed by Kirby and Savage (2008), the model has been criticised for being too simplistic; some claim that grouping the skills underlying reading ability into two broad components is reductionist, overlooking many important skills and how these skills combine to create the complex process of reading. In fact, the SVR does not comprehensively specify the skills which underlie the two broad components of decoding and language comprehension, which has caused some debate regarding what these underlying skills are. This is particularly true in the case of language comprehension. Although they do not specify the cognitive skills which underpin decoding, Gough and Tunmer (1986) define decoding as efficient word recognition, suggesting that decoding can be measured through tasks testing pseudoword reading. Over the years, studies investigating decoding skills have often used measures of both real word and pseudoword reading, as well as measures of phonological awareness, speed of lexical access and letter knowledge (e.g., Adlof, Catts & Little, 2006; Conners, Atwell, Rosenquist & Sligh, 2001; Hulme, Bowyer-Crane, Carroll, Duff & Snowling, 2012; Johnston & Kirby, 2006; Lonigan, Burgess & Anthony, 2000; Muter, Hulme, Snowling & Stevenson, 2004; Silverman, Speece, Harring & Ritchey, 2013). Some studies have also included, or exclusively utilised, a measure of text reading accuracy (e.g., Spooner, Baddeley & Gathercole, 2004; Storch & Whitehurst, 2002); that is, how many reading errors an individual makes when reading out a passage of text. Gough and Tunmer equate language comprehension to listening comprehension, using the latter as a measure of the former in their empirical work on the SVR (Hoover & Gough, 1990), but do not specify the factors underlying this. Since then, researchers have pinpointed vocabulary knowledge and grammatical knowledge as important skills underlying language comprehension (e.g., Droop & Verhoeven, 2003; Muter et al., 2004; Oakhill & Cain, 2012; Storch & Whitehurst, 2002).

Since the conception of the SVR by Gough and Tunmer (1986), some researchers have suggested improvements to the model, such as the inclusion of additional predictors of reading ability which are independent of decoding or language comprehension. For example, several studies have given evidence for the inclusion of reading fluency in the model (e.g., Johnston & Kirby, 2006; Joshi & Aaron, 2000; Kershaw & Schatschneider, 2012; Silverman et al., 2013; Tilstra, McMaster, van den Broek, Kendeou & Rapp, 2009), although evidence from Adlof and colleagues (2006) argues against its inclusion. Another variable that has been suggested for inclusion in the SVR is attentional control (Conners, 2009).

Another commonly cited shortcoming of the SVR is its static nature. Researchers have criticised the fact that the model does not specify how the contribution of decoding and language comprehension skills might change over the course of reading development (e.g., Francis, Kulesz & Benoit, 2018). Hoover and Tunmer (2018) acknowledge this shortcoming, while also asserting that the model has been shown to be valid concurrently across a range of ages. Since the initial proposal of the SVR, evidence has suggested that the link between decoding and reading comprehension becomes progressively weaker with age (e.g., Catts, Hogan & Adlof, 2005; Curtis, 1980; García & Cain, 2014; Gough, Hoover & Peterson, 1996; Juel, 1988; Lonigan et al., 2018; Ouellette & Beers, 2010; Storch & Whitehurst, 2002; Tilstra et al., 2009; Vellutino, Tunmer, Jaccard & Chen, 2007), ostensibly due to an increase and overall lower variability in decoding ability as children grow older and develop reading fluency, while the link between language comprehension and reading comprehension remains strong.

In summary, the SVR has been a leading and highly influential model of reading comprehension over the years since its conception and remains so today. Despite its shortcomings, the SVR has received much support in empirical studies and thus continues to succeed in its purpose to conceptualise reading comprehension "at the broadest level of analysis" (Hoover & Tunmer, 2018, p. 1). The following section will summarise the literature regarding how the decoding and language comprehension skills of EAL children compare to those of FLE children overall, before the individual predictors of reading comprehension are discussed in Section 1.3.

1.2.3 Decoding and Language Comprehension Skills in EAL Children

While research supporting the validity of the SVR in EAL children demonstrates that decoding and language comprehension predict reading comprehension in bilingual children as well as in monolingual children, there is strong evidence suggesting that the decoding skills of EAL children are comparable to those of FLE children. Government data collected through the Phonics Screening Check, an assessment of decoding skill carried out with every Year 1 child in England towards the end of each academic year, demonstrates this; the most recent available data shows that 82% of EAL children and equally 82% of FLE children achieved the expected standard in phonics (DfE, 2019a). The expected standard in the Phonics Reading Check is for children to correctly decode a minimum of 32 words out of a possible 40, consisting of 20 real words and 20 pseudowords. Empirical evidence from the UK also shows EAL and FLE children to have similar levels of decoding ability; for example, several studies have found no significant difference between EAL and FLE children in terms of reading accuracy (Babayiğit, 2014; Hutchinson et al., 2003). Other studies have, in fact, reported EAL children to significantly outperform FLE children on measures of reading accuracy (Bowyer-Crane, Fricke, Schaefer, Lervåg & Hulme, 2017; Burgoyne et al., 2009, 2011; Rosowsky, 2001).

In corroboration with the existing UK-based research, international research has shown language-minority and monolingual children to have approximately comparable decoding skills. For example, in their meta-analysis of studies comparing reading comprehension and its components in language-minority and monolingual children, Melby-Lervåg and Lervåg (2014) reported language-minority children to have largely comparable decoding skills to monolingual children, with an effect size of d = -0.12, showing only a very slight deficit for the language-minority individuals. Overall, there is convincing evidence to suggest that while decoding skills seem to predict reading comprehension in EAL children, EAL children perform at least at the same level as FLE children on measures of decoding. Therefore, taking into account the predictors of reading comprehension according to the SVR, it seems reasonable to assume that the reading comprehension difficulties EAL children experience in comparison to FLE children are a result of difficulties with language comprehension and not with decoding skills.

There is indeed strong evidence from both UK-based and international research that EAL or language-minority children struggle with language comprehension in comparison to their monolingual peers. In their systematic meta-analysis of 82 studies from across the world, Melby-Lervåg and Lervåg (2014) found that language-minority learners scored substantially below monolingual learners in terms of language comprehension, with a large effect size of $d = -1.12$. UK-based research has typically found EAL children to score significantly lower than FLE children on measures of listening comprehension (equated to language comprehension by the authors of the SVR), with small to moderate effect sizes (Babayiğit, 2014; Babayiğit & Shapiro, 2020; Burgoyne et al., 2009, 2011; Hutchinson et al., 2003). In fact, Hutchinson and colleagues found EAL children to score significantly lower in listening comprehension than the FLE group at all time points of their longitudinal study spanning Years 2, 3 and 4. A similar study carried out in the Netherlands also found language-minority learners to score lower than monolingual learners on a measure of listening comprehension at all tested time points (Droop & Verhoeven, 2003). Other international studies have also found monolingual children to outperform language-minority children on measures of listening comprehension (Geva & Farnia, 2012; Kieffer & Vukovic, 2012; Verhoeven & van Leeuwe, 2012). Overall, this research demonstrates that EAL children face a clear disadvantage in language comprehension in comparison to FLE children. While studies measuring listening comprehension do well to demonstrate this, most research investigating the language comprehension skills of EAL children focuses on the sub-components of language comprehension, most commonly vocabulary and grammar. EAL performance on these skills will be discussed in Section 1.3.2.

The fact that EAL children tend to experience difficulties with L2 language comprehension but not L2 decoding suggests that EAL children are able to apply their L1 decoding skills to learning their L2 in a way that is not possible for comprehension skills. The possibility of cross-language transfer of certain skills in bilingual individuals was explored in the Common Underlying Proficiency model, proposed by Cummins (1981) following his Developmental Interdependence Hypothesis (Cummins, 1979), discussed briefly in Section 1.2.1. The Common Underlying Proficiency model posits that bilingual individuals have a "common underlying" language proficiency underpinning their knowledge of both languages, to which the "surface features" of each language are added separately. Thus, Cummins (1981) suggests that some skills are language-independent and can be transferred and applied easily to the learning of additional languages in an individual, while others are language-dependent and thus cannot be. This model was supported in context by Goodrich and Lonigan (2017), who found decoding skills, but not oral language, to be significantly related across languages and thus concluded that language-minority children have a common underlying proficiency across languages for decoding skills but not language-specific skills such as language comprehension.

An abundance of research over the years has further demonstrated cross-language transfer to occur across certain language skills in EAL learners. Research has predominantly focused on phonological awareness, a key component of decoding, demonstrating a correlation between English and L1 phonological awareness across a range of L1s (Atwill, Blanchard, Gorin & Burstein, 2007; Branum-Martin et al., 2006; Cisero & Royer, 1995; De Sousa, Greenop & Fry, 2010; Dickinson, McCabe, Clark-Chiarelli & Wolf, 2004; Durgunoğlu, Nagy & Hancin-Bhatt, 1993; Gottardo, Yan, Siegel & Wade-Woolley, 2001; Lindsey, Manis & Bailey, 2003; López & Greenfield, 2004; Sun-Alperin & Wang, 2011). Word reading accuracy has also been shown to transfer across languages in bilingual individuals, as well as other skills such as reading fluency and orthographic knowledge (e.g., Commissaire, Duncan & Casalis, 2011; Durgunoğlu et al., 1993; Gebauer et al., 2013; Lindsey et al., 2003; Pasquarella, Chen, Gottardo & Geva, 2015; Sun-Alperin & Wang, 2011). Conversely, there is evidence that language comprehension skills do not transfer across languages for bilingual individuals (e.g., Bialystok, Luk & Kwan, 2005; Durgunoğlu et al., 1993; Goodrich, Lonigan, Kleuver & Farver, 2016; Gottardo & Mueller, 2009). Results from meta-analyses of cross-language transfer in bilingual or language-minority individuals have echoed these results, reporting medium to large correlations between L1 and L2 decoding skills, but only very small overall correlations between L1 and L2 oral language or vocabulary knowledge (Melby-Lervåg & Lervåg, 2011; Yang, Cooc & Sheng, 2017).

Overall, it seems that EAL children are indeed able to transfer their decoding skills from their L1 to their L2, but that this does not necessarily occur for their language comprehension skills. This poses an explanation for why EAL children struggle with language comprehension in comparison to FLE children but not with decoding; it seems likely that decoding skills are language-independent, while comprehension skills are language-dependent and thus cannot easily be applied to the learning of a new language. It is important to note, however, that a large majority of the existing studies on cross-language transfer were carried out in the USA with children whose L1 is Spanish, and in fact none of the studies cited in the previous paragraph were carried out in the UK. Because of this, their conclusions are difficult to generalise to the extremely heterogeneous EAL population in the UK. Furthermore, the vast majority of research into cross-language transfer has investigated populations with European L1s, however many of the most common L1s of EAL children in the UK are Asian languages such as Urdu and Panjabi (Hutchinson, 2018) which are orthographically very different to English and thus might not enable cross-language transfer in the same way. Therefore, further research is warranted to investigate cross-language transfer in EAL children in the UK context. It should also be acknowledged that research into cross-language transfer is almost entirely correlational, meaning there is no evidence of a causal link between decoding skills in the L1 and L2. Nevertheless, it is clear that EAL children do not struggle with decoding skills compared to FLE children, and some degree of cross-language transfer of these skills seems to pose a likely explanation.

To summarise the research regarding the reading profiles of EAL children discussed so far, EAL children have been found to exhibit reading comprehension deficits in comparison to monolingual children of the same age. Research into the skills underpinning this disadvantage has revealed EAL children to struggle considerably with language comprehension in comparison to their monolingual peers. In contrast, EAL children seem to perform at the same level as monolingual children on measures of decoding ability, with some studies even demonstrating an EAL advantage on these skills. Given the theoretical structure of reading comprehension, the decoding and language comprehension skills of EAL children and the capability that EAL children possess to transfer their decoding skills across languages, it seems that the reason EAL children have been found to lag behind monolingual children in terms of reading comprehension ability is their language comprehension disadvantage. One aim of the current study is to confirm this supposition through investigation of the linguistic abilities of EAL children across the course of KS2.

1.3 The Predictors of Reading Comprehension in FLE and EAL Children

This section will review and discuss the existing literature pertaining to the predictors of reading comprehension in EAL and FLE children. Evidence demonstrating the relationship between each predictor and reading comprehension in both FLE and EAL populations will be presented, considering also how the contributions of each predictor might differ in strength between the language groups or at different stages of reading development. In addition, research comparing the performance of EAL and FLE children on each predictor will be discussed, in order to determine the aspects of reading comprehension in which EAL children tend to show weaknesses relative to FLE children.

The predictors discussed in this section are grouped into three subsections. The first two subsections, guided by the structure of the SVR, will respectively discuss the decoding skills and language comprehension skills which predict reading comprehension. The third section will discuss two cognitive skills which are pertinent to reading comprehension and which were measured in the current study: non-verbal ability and working memory.

1.3.1 Decoding Skills

As discussed in Section 1.2.1, decoding is described by Gough and Tunmer (1986) as the ability to recognise words accurately and efficiently. Children develop the ability to decode words throughout their childhood as they learn to read, progressing through a number of phases of reading acquisition until they are able to recognise words on sight, without the need to actively apply their knowledge of phonics. Ehri's (2005) phase theory posits that individuals progress through four stages of reading acquisition when learning to read an alphabetic language such as English. The first of these phases is the pre-alphabetic phase, during which children have minimal or no knowledge of the relevant alphabetic system. During this stage, children may be able to recognise some words, though only through the look or shape of the word; for example, they may be able to recognise their own name in writing but will not be able to make connections between the letters and the sounds which they represent. Following this, children begin to develop decoding skills in the partial alphabetic phase, during which they learn about graphemes (letters) and phonemes (letter sounds) and begin to use this knowledge to detect some of the sounds within words. According to Ehri, children then enter the full alphabetic phase, during which they develop a full understanding of grapheme-phoneme correspondences and learn to identify all of the phonemes in words, thus gaining the ability to decode unfamiliar words, and also begin to use their oral language knowledge to support their reading. Finally, children enter the consolidated alphabetic phase, during which they learn to consolidate their knowledge of grapheme-phoneme correspondence into larger chunks of letters such as syllables and indeed whole words, and learn to recognise these across different words, such as rhymes. During this final phase, children also start to retain large numbers of words in their memory, allowing them to recognise words without the need to break them down into smaller chunks in order to successfully read them. Overall, the ability to accurately and efficiently decode words seems to rely on a gradual familiarisation with graphemes, phonemes and the correspondence between the two, until children are able to recognise and sound out groups of letters and indeed whole words. Measures of decoding ability should therefore seek to test and quantify an individual's grasp of such processes. Word reading accuracy, phonological awareness and speed of lexical access are commonly considered to be important subcomponents of decoding, and thus tests of these abilities are often utilised to measure decoding ability.

There is a substantial amount of evidence demonstrating a strong association between general decoding ability and reading comprehension; many studies have found measures of text reading accuracy or composite measures of decoding skills to significantly predict reading comprehension (e.g., Kendeou, Savage & van den Broek, 2009; Kendeou, van den Broek, et al., 2009; Spooner et al., 2004; Storch & Whitehurst, 2002). Furthermore, a meta-analysis of 110 studies investigating the relationship between decoding and reading comprehension by García and Cain (2014) found an average correlation of $r = .74$ between decoding and reading comprehension. García and Cain also highlight that while decoding and reading comprehension are related throughout childhood, the strength of this relationship decreases over time as the decoding abilities of children grow towards ceiling level, with average correlations between decoding and reading comprehension of $r = .74$-.86 children below 10 years of age and of $r = .41$-.64 in children above 10 years of age.

There is also evidence in the literature to demonstrate that general L2 decoding skills predict L2 reading comprehension in language-minority children in much the same way as in monolingual children (e.g., Babayiğit, 2014, 2015; Bonifacci & Tobia, 2017; Kieffer & Vukovic, 2012; Proctor, Carlo, August & Snow, 2005). In a meta-analysis investigating the correlates of L2 reading comprehension in language-minority children, Jeon and Yamashita (2014) found an overall correlation of $r = .56$ between general decoding ability and reading comprehension across 18 studies. While Jeon and Yamashita did not compare this relationship across different age groups of children, a general decrease in the contribution of decoding to reading comprehension over time was observed, with overall correlations of $r = .46$ found for adolescent or adult populations and $r = .61$ for child populations.

While there is strong evidence demonstrating the predictive relationship between general measures of decoding and reading comprehension, it is important to consider different measures of decoding separately. For example, García and Cain (2014) found the measure of decoding used in studies investigating the relationship between decoding and reading comprehension to be a significant moderator of the relationship; overall correlation coefficients varied from $r = .48$ to .86 across different decoding measures. With this in mind, this section will discuss the extent to which three common measures of decoding (word reading, phonological awareness and speed of lexical access) predict reading comprehension ability in both monolingual and language-minority children, and will also review the research comparing the performance of the two language groups on these measures.

1.3.1.1 Word Reading

Effective single word reading is commonly believed to develop through the employment of two strategies by individuals as they learn to read: sight word reading and phonological decoding (Aaron et al., 1999). Sight word reading, also known as visual word recognition, refers to the ability to automatically read and pronounce a word which has been encountered before by retrieving it from one's mental lexicon, while phonological decoding refers to using one's knowledge of grapheme-phoneme correspondences to match letters to sounds and thus reason out the pronunciation of a word (Coltheart, 2006). As such, beginners to reading tend to rely almost exclusively on phonological decoding to sound out words, but as they become more skilled readers and their mental lexicon grows, they are able to read many words by sight, making their reading more efficient and freeing up cognitive resources for higher-order reading processes. This distinction between word reading strategies is also reflected in the Dual Route Cascaded Model (Coltheart, Rastle, Perry, Langdon & Ziegler, 2001), which refers to a lexical route to word reading equivalent to sight word reading, and a sub-lexical route equivalent to the process of phonological decoding.

Tasks used to measure word reading ability differ in the extent to which they depend, if at all, upon sight word reading and phonological decoding abilities. Typically, word reading tasks require participants to read aloud lists of words, after which participants are given a score equal to the number of words pronounced correctly. Such tasks may differ in the types of words included in the task; typically, these types can be regular words, exception or irregular words, and non-words or pseudowords. Regular words (e.g., *them*) are words which consistently follow grapheme-phoneme correspondence rules, while exception or irregular words are words which do not (e.g., *come*).

Successfully reading exception words requires individuals to recognise the words on sight, while successfully reading non-words relies solely on phonological decoding. In contrast, either strategy can be employed to successfully read regular words; the strategy used will often depend on the age of the individual and the frequency of the words. The majority of the studies in the literature investigating word reading and reading comprehension tested participants on real word reading only, or a combination of word types; for this reason, it is difficult to separate the literature into categories based on the strategy tested. Therefore, this section will focus on word reading in its broadest sense, unless when stated otherwise.

There is substantial evidence in the literature demonstrating that word reading is an important predictor of reading comprehension outcomes (e.g., Adlof et al., 2006; Johnston & Kirby, 2006; Lervåg et al., 2018; Muter et al., 2004; Ouellette & Beers, 2010; Storch & Whitehurst, 2002; Tilstra et al., 2009). In their meta-analysis investigating the link between decoding and reading comprehension, García and Cain (2014) found overall significant correlations of r = .69-.86 between real word reading tasks and reading comprehension, and overall significant correlations of r = .56-.66 between pseudoword reading tasks and reading comprehension. Having measured phonological decoding and sight word reading separately using pseudoword reading tasks as well as an irregular word reading task, Ouellette and Beers (2010) found both word reading strategies to uniquely predict reading comprehension ability. In Grade 1 children, after controlling for phonological awareness, phonological decoding and sight word reading uniquely accounted for 20.4% and 5.4% of the variance in reading comprehension scores respectively. In Grade 6 children, after controlling for phonological awareness, sight word reading accounted for an additional 12.6% of the variance in reading comprehension, while phonological decoding was not a significant predictor. This reflects a decline in reliance on phonological decoding and an increase in the use of sight word reading as children grow older and become more skilled readers. In addition, these results show a general decline in the influence of overall word reading ability on reading comprehension as children grow older; this is reflected in other similar studies (e.g., Adlof et al., 2006; Storch & Whitehurst, 2002; Tilstra et al., 2009).

L2 word reading has also widely been shown to predict L2 reading comprehension in EAL children in the UK (e.g., Babayiğit, 2015; Babayiğit & Shapiro, 2020; Beech & Keys, 1997; Bowyer-Crane et al., 2017; Burgoyne et al., 2011) and language-minority children internationally (e.g., Droop & Verhoeven, 2003; Farnia & Geva, 2013; Lervåg & Aukrust, 2010; Lesaux et al., 2007; Mancilla-Martinez & Lesaux, 2010; Verhoeven & van Leeuwe, 2012). This relationship is much the same as in monolingual children, with evidence showing the influence of word reading to decrease with age in a similar way (e.g., Droop & Verhoeven, 2003; Verhoeven & van Leeuwe, 2012). In the literature, EAL or language-minority children have typically been found to perform at the same level as monolingual children on a variety of word reading measures, both in the UK (e.g., Babayiğit, 2015; Babayiğit & Shapiro, 2020; Beech & Keys, 1997; Hoxha & Sumner, 2021; Hutchinson et al., 2003) and internationally (e.g., Aarts & Verhoeven, 1999; Chiappe & Siegel, 1999; Farnia & Geva, 2013; Geva, Yaghoub-Zadeh & Schuster, 2000; Jongejan, Verhoeven & Siegel, 2007; Lervåg & Aukrust, 2010; Verhoeven & van Leeuwe, 2012; Xu et al., 2021). In fact, some studies have found language-minority learners to outperform monolingual learners on such measures (Bowyer-Crane et al., 2017; Burgoyne et al., 2009, 2011; Raudszus et al., 2018). The fact that language-minority children do not struggle with word reading reflects evidence that they are able to transfer word reading skills from their L1 to their L2 (e.g., Durgunoğlu et al., 1993).

While word reading skills have been shown not to differ between EAL and FLE children and to predict reading comprehension in both language groups, there is some evidence that EAL learners employ word reading strategies differently to monolingual children when reading. A study by Chiappe and Siegel (2006) investigated the reading strategies used by FLE and EAL children in Canada when reading regular words, exception words and pseudowords, and found that the EAL children were more likely to use phonologically decode words than the FLE children, and thus were more prone to making pronunciation errors on words previously unfamiliar to them. Similar results were found by Mumtaz and Humphreys (2001), who found that EAL children in the UK made more pronunciation errors than FLE children when reading irregular words. These results suggest that EAL children have a greater reliance on the sub-lexical route to word reading than FLE children do, and that this causes difficulty when reading irregular words.

Overall, there is substantial evidence in the literature that word reading predicts reading comprehension similarly in both monolingual and language-minority populations, and that the two language groups do not differ in their word reading ability. Based on the evidence discussed, it seems that the reading comprehension disadvantage observed in EAL children is not a result of lower word reading abilities. The following sections will consider two other common measures of decoding ability and how they relate to reading comprehension in monolingual and language-minority populations.

1.3.1.2 Phonological Awareness

Phonological awareness can be defined as the ability to consciously recognize and manipulate the sounds of words within a language (Wagner & Torgesen, 1987). This ability is distinct from awareness of how sounds are represented in written language as well as awareness of the meaning of language (Sodoro, Allinder & Rankin-Erickson, 2002). A wide range of tasks are used to measure phonological ability; these include, but are not limited to, measures of awareness of phonemes, syllables or rhymes, and often require participants to identify sounds within words, segment words into sounds or pronounce words after deleting or switching certain sounds contained within them. Phonological awareness has long been identified as an important factor in learning to read (e.g., Snowling, 2000; Wagner & Torgesen, 1987). Research has shown phonological awareness to causally predict later reading ability after controlling for variables such as SES and IQ (e.g., Bradley & Bryant, 1983; Wagner, Torgesen & Rashotte, 1994), with Bus and van Ijzendoorn (1999) showing it to account for 12% of the variation in reading ability. Research has also suggested that the causal relationship between phonological awareness and reading ability is bidirectional; that is, learning to read also causes an increase in phonological awareness (e.g., Nation & Hulme, 2011; Perfetti, Beck, Bell & Hughes, 1987; Wagner et al., 1994).

Phonological awareness is often viewed as a component skill of decoding, and has commonly been linked to word reading ability (e.g., Conners et al., 2001; Hulme et al., 2012; Melby-Lervåg, Lyster & Hulme, 2012; Nation & Snowling, 2004). However, its link to reading comprehension is somewhat less clear-cut in the literature; while there is evidence of a predictive relationship between phonological awareness and reading comprehension (e.g., Cain, Oakhill & Bryant, 2000; Gottardo, Stanovich & Siegel, 1996; Muter et al., 2004; Nation & Snowling, 2004; Ouellette & Beers, 2010; Storch & Whitehurst, 2002; Vellutino et al., 2007), some evidence identifies phonological awareness as a unique predictor of reading comprehension while other studies conclude that it only indirectly predicts reading comprehension through word reading. There is also some evidence that phonological awareness has very little effect on reading comprehension (e.g., Krashen, 2001). It is likely that the discrepancies in the findings of these studies are due to differences in the age of the participating children or the particular test of phonological awareness used; as discussed above, decoding abilities develop throughout childhood and correspondingly, the tasks used to assess skills such as phonological awareness often vary with the age of participants.

Phonological awareness has also been found to influence reading comprehension outcomes in language-minority children. A meta-analysis by Jeon and Yamashita (2014) found an overall correlation of $r = .48$ between L2 phonological awareness and L2 reading comprehension in language-minority samples, and empirical studies have found phonological awareness to be similarly important to reading comprehension in language-minority individuals and monolingual individuals (e.g., Erdos, Genesee, Savage & Haigh, 2011; Farnia & Geva, 2013; Geva & Farnia, 2012; Lesaux & Siegel, 2003). When comparing the phonological awareness of language-minority and monolingual children, some research has found no significant difference between the groups (Bowyer-Crane et al., 2017; Chiappe & Siegel, 1999; Chiappe, Siegel & Wade-Woolley, 2002; Geva & Farnia, 2012; Harrison et al., 2016; Hoxha & Sumner, 2021; Jongejan et al., 2007; Lesaux et al., 2007; Verhoeven, 2000) while other research has found language-minority children to actually outperform monolingual children (Campbell & Sais, 1995; Farnia & Geva. 2013; Lesaux & Siegel, 2003; Marinova-Todd, Zhao & Bernhardt, 2010; Roessingh & Elgie, 2009). In a meta-analysis, Melby-Lervåg and Lervåg (2014) found no significant difference in phonological awareness between language-minority and monolingual children. These results reflect that, as mentioned previously, bilingual children are able to transfer their phonological awareness across languages and hence are not disadvantaged in their L2 in terms of phonological awareness (e.g., Melby-Lervåg & Lervåg, 2011). Overall, the discussed evidence demonstrates that language-minority children, commonly performing at the same level as monolingual children or indeed higher across the literature, do not seem to struggle with phonological awareness. This suggests that phonological awareness does not play a causal role in the reading comprehension disadvantage faced by EAL children.

1.3.1.3 Speed of Lexical Access

Speed of lexical access, also often known as naming speed, refers to how quickly and accurately an individual is able to name sets of stimuli (McMillen, Jarmulowicz, Mackay & Oller, 2020). This process includes an individual directing attention onto the stimuli, integrating visual information from the stimuli with stored orthographic and phonological representations, retrieving phonological labels and finally articulation (Wolf & Bowers, 1999). Speed of lexical access is measured using rapid automatised naming (RAN) tasks, which visually present sets of high-frequency letters, digits, colours or objects in a random order which participants are asked to read out as quickly as possible. The first of these tasks were created by Denckla and Rudel (1976). Speed of lexical access has often been linked to word reading; for example, a meta-analysis of 151 studies by Araújo, Reis, Petersson and Faísca (2015) found an overall correlation of r = .45 between the two. Similarly, Swanson, Trainin, Necoechea and Hammill (2003) found an overall correlation of r = .41 between speed of lexical access and word reading across 33 samples. The reason for this relationship has been debated in the literature; some researchers (e.g., Share, 1995; Torgesen, Wagner, Rashotte, Burgess & Hecht, 1997) suggest that because RAN tasks measure the ease by which individuals can retrieve phonological information from memory, speed of lexical access is strongly related to phonological awareness and works indirectly through phonological awareness to predict word reading. However, there is evidence that speed of lexical access predicts reading ability above and beyond the contribution of phonological awareness, as summarised in a review by Wolf, Bowers and Biddle (2000). Other research (e.g., Bowers & Newby-Clark, 2002; Wolf & Bowers, 1999) posits that speed of lexical access is related to orthographic processing and thus boosts word reading skills through allowing faster recognition of orthographic patterns and chunks. Despite these theoretical debates, the relationship between speed of lexical access and reading ability is well established in the literature.

Turning now to the relationship between speed of lexical access and reading comprehension, there is considerable evidence that speed of lexical access predicts reading comprehension (Arnell, Joanisse, Klein, Busseri & Tannock, 2009; Georgiou, Manolitsis, Nurmi & Parrila, 2010; Johnston & Kirby, 2006; Kirby, Parrila & Pfeiffer, 2003; Manis, Doi & Bhadha, 2000; Neuhaus, Foorman, Francis & Carlson, 2001). For example, Manis and colleagues found performance on letter- and digit-naming RAN tasks to uniquely account for 5.1-11.3% of the variance in reading comprehension in Grade 2 children, having controlled for vocabulary knowledge and phonological awareness. In their longitudinal study, Kirby and colleagues found kindergarten performance on colour- and picture-naming RAN tasks to uniquely predict reading comprehension scores between Grade 3 and Grade 5. Interestingly, the contribution of RAN increased in the later grades, while the contribution of phonological awareness decreased over time. It has also been suggested that speed of lexical access indirectly predicts reading comprehension through word reading (e.g., Bowers &

Ishaik, 2003; Scarborough, 1998); however, it remains clear that speed of lexical access is an influential factor in reading comprehension ability.

There is evidence that speed of lexical access predicts reading comprehension in language-minority children in much the same manner as in monolingual samples (e.g., Farnia & Geva, 2013; Geva & Farnia, 2012; Swanson, Sáez, Gerber & Leafstedt, 2004). Studies investigating speed of lexical access in language-minority children in comparison to monolingual children have typically found no significant difference between the groups (e.g., Farnia & Geva, 2013; McMillen et al., 2020) or indeed that language-minority children significantly outperform monolingual children (e.g., Geva & Farnia, 2012; Geva & Yaghoub Zadeh, 2006; Jongejan et al., 2007; Lesaux & Siegel, 2003). These results reflect the literature pertaining to word reading and phonological awareness, and similarly suggest that speed of lexical access is not a cause of the difficulties with reading comprehension faced by language-minority children.

Taken together, the discussed literature on decoding skills paints a clear picture that the relationship between decoding skills and reading comprehension is very similar in language-minority and monolingual children, and that decoding does not seem to be an area of relative difficulty for language-minority children. The following sections will discuss the language comprehension skills necessary for successful reading comprehension, and compare the performance of language-minority and monolingual children on these skills.

1.3.2 Language Comprehension Skills

Language comprehension, as discussed in Section 1.2.2, refers to the ability to draw meaning from words and sentences while reading them. Language comprehension is most commonly measured using tests of vocabulary knowledge, grammatical knowledge or listening comprehension. As such, this section will summarise the research on how these three skills relate to reading comprehension and how language-minority and monolingual children compare on these skills.

1.3.2.1 Vocabulary Knowledge

Broadly, vocabulary knowledge refers to the words in an individual's mental lexicon of which the individual understands the meaning. While a relatively simple concept at face value, vocabulary knowledge is in reality multidimensional and complex, requiring knowledge of various aspects of each word such as the spoken and written forms of a word, the meanings and applications associated with the word, the word's grammatical function and the word's collocations (Nation, 2005). Within the literature, vocabulary knowledge has been conceptualised and thus measured in a number of ways. Researchers often distinguish between receptive vocabulary, which refers to the words an individual recognises, either in written or spoken form, and expressive vocabulary, which refers to the words an individual is able to actively use in writing or speech. Typically, measures of receptive vocabulary present participants with sets of pictures and ask them to point to the pictures representing a series of spoken words, while measures of expressive vocabulary often require participants to define a set of words presented to them orally or visually. Ostensibly due to the receptive nature of reading, receptive vocabulary skills are more commonly associated with reading and are thus used more often when researching literacy (Jeon & Yamashita, 2014); however, many researchers employ measures of both receptive and expressive vocabulary.

There is a wealth of strong evidence in the literature suggesting a predictive link between vocabulary knowledge and reading comprehension. Both receptive and expressive vocabulary have been found to predict reading comprehension in monolingual learners (e.g., Duff, Reen, Plunkett & Nation, 2015; Muter et al., 2004; Nation & Snowling, 1998, 2004; Verhoeven & van Leeuwe, 2008). Indeed, Duff and colleagues found measures of receptive and expressive vocabulary collected in infancy to together account for 18% of the variance in reading comprehension in a group of children aged between 4 and 9 years of age, showing this relationship to exist longitudinally. In fact, a study by Schmitt, Jiang and Grabe (2011) found that in order for an individual to infer the general meaning of a text, 95-98% of the vocabulary used in the text must be known to them. Additionally, there is evidence to suggest that the influence of vocabulary on reading comprehension increases with age as children become more proficient decoders (e.g., de Jong & van der Leij, 2002; Muter et al., 2004; Roth, Speece & Cooper, 2002; Storch & Whitehurst, 2002).

Measures of both receptive and expressive vocabulary knowledge have also been found to predict reading comprehension outcomes in EAL and other language-minority children (e.g., Babayiğit, 2015; Burgoyne et al., 2011; Geva & Farnia, 2012; Kieffer, 2012; Kieffer & Vukovic, 2012; Lesaux, Crosson, Kieffer & Pierce, 2010; Nakamoto et al., 2007; Proctor et al., 2005). In addition, in their meta-analysis of the predictors of reading comprehension in language-minority learners, Jeon and Yamashita (2014) found an overall correlation of $r = .79$ between measures of vocabulary knowledge and reading comprehension. In fact, vocabulary knowledge has been found to be even more important for reading comprehension in language-minority learners than in monolingual learners (e.g., Droop & Verhoeven, 2003; Lervåg & Aukrust, 2010; Limbird, Maluch, Rjosk, Stanat & Merkens, 2014). There is also some evidence suggesting that different types of vocabulary knowledge are differentially predictive between EAL and FLE learners; Burgoyne and colleagues (2009) found receptive vocabulary alone to uniquely predict reading comprehension in a group of FLE children and expressive vocabulary alone to be a unique predictor in a group of EAL children. Hutchinson and colleagues (2003) also found expressive vocabulary to uniquely predict reading comprehension in EAL but not FLE children. It may be that EAL children are less able to use their receptive vocabulary skills to aid them in comprehension by referring back to the text than FLE children, and thus rely more on their expressive vocabulary knowledge.

Studies comparing the vocabulary knowledge of EAL and FLE learners during primary school have consistently found EAL learners in the UK to have significantly lower English vocabulary knowledge than their FLE peers (Babayiğit, 2014; Burgoyne et al., 2009, 2011, 2013; Dixon et al., 2022; Hessel & Murphy, 2018; Hutchinson et al., 2003; Mahon & Crutchley, 2006). Research suggests that this gap in vocabulary knowledge between EAL and FLE children decreases over time throughout primary school (e.g., Mahon & Crutchley, 2006), but does not close completely; Hutchinson and colleagues reported that EAL children consistently lagged 2 years behind FLE children on measures of vocabulary between Year 2 and Year 4. A disadvantage in receptive vocabulary has also been identified in EAL children aged 13 to 14 (Cameron, 2002), suggesting that the gap in vocabulary knowledge between EAL and FLE children persists into secondary school, although less research has been carried out with secondary school children. International research echoes the existing findings from the UK, showing similar gaps in vocabulary knowledge between language-minority and monolingual children (e.g., Bialystok, Luk, Peets & Yang, 2010; Droop & Verhoeven, 2003; Farnia & Geva, 2011; Geva & Massey-Garrison, 2013; Lervåg & Aukrust, 2010; Limbird et al., 2014; Mancilla-Martinez & Lesaux, 2011; Raudszus et al., 2018; Verhallen & Schoonen, 1993, 1998; Xu et al., 2021). In addition, international research into the reasons behind the vocabulary disadvantage observed in EAL children has found factors pertaining to English exposure such as the length of English exposure, the quantity and quality of English exposure at home, and exposure to English digital media such as video games, to significantly predict EAL vocabulary knowledge (e.g., Paradis, 2011; Paradis & Jia, 2017; Paradis, Tulpar & Arppe, 2017; Sundqvist, 2019).

Not only does education require an understanding of everyday language, but it also requires proficiency in “academic language”; that is, in words which often occur in academic situations but not in ordinary conversation. The concept of academic language has been clarified in the Three Tier Model (Beck, McKeown & Kucan, 2002), which splits vocabulary into three tiers. The second tier, words used extensively in the curriculum and words with multiple meanings, and the third tier, content-specific vocabulary, together make up academic language. Academic vocabulary knowledge has been found to predict academic achievement in primary school beyond the contribution of general vocabulary knowledge (Schuth, Köhne & Weinert, 2017). DiCerbo, Anstrom, Baker and Rivera (2014) review the literature surrounding the concept and definition of academic language and the importance of academic language in the education of EAL children. As discussed, for example, by Biemiller and Boote (2006), both EAL and FLE children with low levels of academic vocabulary knowledge have been found to achieve less well academically than children with good academic vocabulary knowledge. According to Murphy and Unthiah (2015), there are approximately 7,000 word families in the English language which fall into the category of academic language; an immense number for EAL children to learn. Cummins (1984) estimated that EAL children take between 5 and 7 years to develop full English academic language proficiency, and this figure has been replicated in more recent research both in the US (Hakuta, Butler & Witt, 2000) and in the UK (Demie, 2013). These findings demonstrate the huge barrier that may be faced by EAL children in preparing themselves for academic success; although they may develop full academic language proficiency in time, they are likely to fall behind academically prior to this and may struggle to catch up again even after developing full proficiency. The length of time taken for EAL children to develop academic language proficiency is especially concerning for EAL children who arrive in the UK education system late.

Overall, the literature demonstrates a clear link between vocabulary knowledge and reading comprehension outcomes in both monolingual and language-minority learners. However, language-minority learners have widely been found to struggle with vocabulary knowledge in comparison to their monolingual peers throughout primary school and into secondary school. Given the strong link between vocabulary and reading comprehension, it seems highly likely that the reading comprehension disadvantage observed in EAL children is, in part, due to their weaker vocabulary knowledge. Indeed, Babayiğit (2015) found that an observed EAL disadvantage in reading comprehension became non-significant when group differences in vocabulary knowledge were controlled for. The following section will turn to the relationship between grammatical knowledge and reading comprehension in language-minority and monolingual learners.

1.3.2.2 Grammatical Knowledge

Grammatical knowledge comprises two primary aspects: syntactic knowledge, which refers to the understanding of how sentences are structured (e.g., Tunmer & Bowey, 1984), and morphological awareness, which refers to the understanding of how words themselves are structured internally (e.g., Carlisle, 1995). Measures of syntactic knowledge often require participants to correct the grammatical structure of sentences, while tests of morphological awareness typically require participants to give the correct form of a word based on analogical examples or in order to correctly complete sentences.

The contribution of grammatical knowledge to reading comprehension is relatively under-researched in comparison to the contribution of other skills such as vocabulary knowledge, but there is evidence to suggest that both syntactic and morphological awareness uniquely predict reading comprehension ability in monolingual learners (Brimo, Apel & Fountain, 2017; Deacon, Kieffer & Laroche, 2014; Deacon & Kirby, 2004; Kirby et al., 2012; Tong & McBride, 2017; Willows & Ryan, 1986), as do combined measures of general grammatical ability (Adlof, Catts & Lee, 2010; Muter et al., 2004; Silva & Cain, 2015). This relationship is not surprising, given the need to understand both individual words and sentences in order to comprehend a passage of text (Oakhill, Cain & Bryant, 2003). There is, however, contradictory evidence suggesting that measures of grammatical ability do not account for any variance in reading comprehension after controlling for the effect of other factors such as vocabulary knowledge (Bowey & Patel, 1988; McCutchen, Green & Abbott, 2008; Oakhill & Cain, 2012; Oakhill et al., 2003; Vellutino et al., 2007). Nevertheless, it is clear from the literature that grammatical knowledge is strongly related to reading comprehension ability.

Despite the conflicting evidence regarding the unique role of grammatical skills in predicting reading comprehension, grammatical skills are often included in studies investigating the predictors of reading comprehension in EAL children, although still to a lesser extent than vocabulary knowledge. There is substantial evidence in the literature that grammatical knowledge is related to reading comprehension in L2 learners. For example, Jeon and Yamashita (2014) found L2 grammatical knowledge and L2 reading comprehension to be strongly related, with a mean correlation coefficient of $r = .85$ calculated from the results of 16 studies. Jeon and Yamashita also calculated an average correlation coefficient for the relationship between L2 morphological knowledge and L2 reading comprehension, which stood at $r = .61$ across six studies. Furthermore, several studies have shown grammatical knowledge to uniquely predict reading comprehension scores in language-minority learners (Babayiğit, 2014; Babayiğit & Shapiro, 2020; Farnia & Geva, 2013; Geva & Farnia, 2012; Gottardo, Mirza, Koh, Ferreira & Javier, 2018; Jeon, 2011; Kieffer & Lesaux, 2008). For example, Gottardo and colleagues found both syntactic knowledge and morphological awareness to significantly predict reading comprehension in EAL children aged between 8 and 13, uniquely accounting for 9% and 4.4% of the variance in reading comprehension respectively. Typically, the relationship between grammar and reading comprehension has been found to be comparable between language-minority and monolingual learners (e.g., Babayiğit, 2014; Lesaux et al., 2007; van Gelderen et al., 2003), although evidence from a study by Jongejan and colleagues (2007) suggests that grammar is not a significant predictor of reading comprehension for language-minority learners only, due to the dominant influence of their weaker vocabulary skills.

While grammatical knowledge has been shown to be an important predictor of reading comprehension in both language-minority and monolingual learners, EAL children in the UK have been shown to perform at a significantly lower level on measures of grammatical knowledge than FLE children. This was, for example, demonstrated at all time points in Hutchinson and colleagues' (2003) longitudinal study of the predictors of reading comprehension across Years 2, 3 and 4. Studies by Babayiğit (2014) as well as Babayiğit and Shapiro (2020) also found an achievement gap in general grammatical knowledge in favour of FLE children, with large effect sizes in both cases. International research from the Netherlands and Canada corroborates these findings (e.g., Droop & Verhoeven, 2003; Farnia & Geva, 2013; Geva & Farnia, 2012; Lesaux et al., 2007). From this evidence, it seems that EAL children struggle with grammatical understanding in English in comparison to their monolingual peers, and that given the established link between grammar and reading comprehension, this gap in grammatical ability is likely to contribute to the difficulties that language-minority learners face with reading comprehension to some extent.

1.3.2.3 Listening Comprehension

Listening comprehension refers to the ability to understand and make sense of spoken language (Nadig, 2013). Typically, assessments of listening comprehension require participants to listen to passages of spoken text and to then answer questions testing both their literal and inferential comprehension of the text. Listening comprehension involves a range of processes over and above the comprehension of single words, and as such is a more complex construct than vocabulary knowledge (Florit, Roch & Levorato, 2011). Indeed, as discussed in Section 1.2.2, Gough and Tunmer (1986) equate the broad language comprehension component of their SVR to listening comprehension; this suggests that listening comprehension plays a vital role in reading, but is made up of several sub-components. For example, listening comprehension has been shown to require vocabulary knowledge, grammatical knowledge, inferential skills and verbal working memory; these skills together were found to explain 95% of the variance in listening comprehension by Lervåg and colleagues (2018). Vocabulary and grammar in particular have often been shown to predict listening comprehension outcomes (e.g., Kim, 2015; Lepola, Lynch, Laakkonen, Silvén & Niemi, 2012; Wang & Treffers-Daller, 2017).

Given the complex nature of listening comprehension, there is some difference of opinion within the literature regarding whether vocabulary, grammar and listening comprehension should be considered together or as separate constructs when investigating the predictors of reading comprehension. To illustrate, having shown vocabulary and grammar to be sub-components of listening comprehension, Lervåg and colleagues (2018) found that vocabulary knowledge and grammar did not explain any additional variance in reading comprehension after accounting for the contribution of listening comprehension. Babayiğit and Stainthorp (2014) found that by Grade 2, listening comprehension made no unique contribution to reading comprehension scores after accounting for vocabulary and grammar. However, several studies have shown vocabulary knowledge and listening comprehension to concurrently explain unique portions of variance in reading comprehension, suggesting that the two should be regarded as distinct constructs and hence justifying the inclusion of both vocabulary knowledge and listening comprehension measures in studies of reading comprehension (Braze, Tabor, Shankweiler & Mencl, 2007; de Jong & van der Leij, 2002; Nation & Snowling, 2004; Ouellette & Beers, 2010; Protopapas, Mouzaki, Sideridis, Kotsolakou & Simos, 2013; Tunmer & Chapman, 2012).

Given the overlap between vocabulary knowledge, grammar knowledge and listening comprehension, many studies investigating the predictors of reading comprehension use only vocabulary and grammar measures to assess language comprehension. Despite the relative lack of research including listening comprehension, it is well-established that listening comprehension is an important predictor of reading comprehension in monolingual children (e.g., Babayiğit & Stainthorp, 2011; Diakidoy, Stylianou, Karefillidou & Papageorgiou, 2005; Nation and Snowling, 2004; Tilstra et al., 2009). Evidence also suggests that the contribution of listening comprehension to reading comprehension increases with age (Catts, Adlof, Hogan & Weismer, 2005; Kershaw & Schatschneider, 2012; Tilstra et al., 2009).

There is also evidence across the literature demonstrating that listening comprehension is a significant predictor of reading comprehension in language-minority children (Bonifacci & Tobia, 2017; Burgoyne et al., 2011; Droop & Verhoeven, 2003; Geva & Farnia, 2012; Lesaux et al., 2010; Nakamoto, Lindsey & Manis, 2012). Indeed, Verhoeven and van Leeuwe (2012) found the predictive pattern between listening comprehension and reading comprehension to be comparable across the language groups, with the contribution of listening comprehension increasing over time in both groups. In addition, Jeon and Yamashita (2014) found an overall mean correlation of r = .77 between L2 listening comprehension and L2 reading comprehension in language-minority children. While listening comprehension is vital to reading comprehension in language-minority children, research has demonstrated that EAL learners consistently struggle with listening comprehension in comparison to FLE learners both in the UK and internationally (see Section 1.2.3). In summary, the literature has demonstrated a clear link between listening comprehension and reading comprehension in both monolingual and language-minority children, and there is substantial evidence that EAL children struggle with listening comprehension compared to their monolingual peers; it therefore stands to reason that difficulty with listening comprehension might also play a role in the lower reading comprehension abilities observed in EAL children.

In summary, it seems that EAL children are often found to struggle with comprehension skills such as vocabulary, grammar and listening comprehension in comparison to their FLE peers, and that these weaknesses are likely to contribute to their commonly observed difficulties with reading comprehension. Furthermore, there is evidence that comprehension skills, particularly vocabulary knowledge, are even stronger predictors of reading comprehension for language-minority children than for monolingual children (e.g., Babayiğit, 2014; Droop & Verhoeven, 2003; Geva & Farnia, 2012; Hutchinson et al., 2003; Lervåg & Aukrust, 2010; Lesaux et al., 2010; Stuart, 2004; Verhoeven, 2000); this clearly highlights the importance of targeting comprehension skills in EAL children to aid their reading development. The following section will discuss two cognitive skills which are often included in studies investigating the predictors of reading comprehension and how they relate to reading comprehension in monolingual and language-minority learners.

1.3.3 Cognitive Skills

In addition to decoding and language comprehension skills, a number of cognitive factors have been shown to influence reading comprehension ability. This section will discuss the literature surrounding the roles of working memory and non-verbal ability in reading comprehension in both monolingual and language-minority learners, as well as how the two groups compare on these measures.

1.3.3.1 Working Memory

Working memory refers to the system by which information is actively held and processed for a temporary period in order to support other cognitive tasks such as reading or problem solving (Baddeley, 1983). In their seminal paper, Baddeley and Hitch (1974) proposed a model of working memory consisting of three components; the phonological loop, which manages the temporary storage of spoken and written material, the visuospatial sketchpad, which manages the temporary storage of visual and spatial information and the central executive, which drives the working memory system, managing cognitive tasks such as mental arithmetic and allocating information to the phonological loop and visuospatial sketchpad. Working memory can be measured in many different ways involving the temporary storage and manipulation of information, but a distinction is often made in the literature based on whether this information is verbal or non-verbal. A measure of verbal working memory, for example, might be a backward digit recall task in which participants hear sets of digits and are required to recite them in reverse order. Conversely, tasks measuring non-verbal working memory might require participants to observe sequences of blocks being tapped and to then tap the blocks themselves in reverse order. Working memory has widely been shown to predict performance in various aspects of academic achievement including reading, mathematics and science, especially in the primary school years (e.g., Gathercole, Pickering, Knight & Stegmann, 2004).

There is considerable evidence to suggest that verbal working memory in particular predicts reading comprehension in monolingual learners (e.g., Cain, Oakhill & Bryant, 2004; Cain, Oakhill & Lemmon, 2004; Montgomery & Evans, 2009; Seigneuric & Ehrlich, 2005; Seigneuric, Ehrlich, Oakhill & Yuill, 2000). For example, Seigneuric and colleagues (2000) found verbal working memory tasks to uniquely account for 5-10% of the variance in reading comprehension above the contributions of decoding and vocabulary knowledge. In addition, a meta-analysis by Daneman and Merikle (1996) found verbal working memory to be significantly correlated with reading comprehension across 77 studies. Conversely, non-verbal working memory does not seem to uniquely predict reading comprehension (e.g., Seigneuric et al., 2000). This result was reflected in a meta-analysis by Carretti, Borella, Cornoldi and De Beni (2009), which found verbal working memory to be more strongly associated with reading comprehension than non-verbal working memory. The link between working memory and reading comprehension can be explained by the need to temporarily store words and their meanings in the mind to be integrated with existing knowledge in order to comprehend a passage of text (Cain & Oakhill, 2008). However, there is some evidence that working memory does not predict reading comprehension after accounting for the contributions of other factors such as decoding and vocabulary skills (e.g., Oakhill & Cain, 2012), suggesting that the relationship might depend on the demands of the specific working memory task being used.

Verbal working memory has also been shown to predict reading comprehension outcomes in EAL children (e.g., Farnia & Geva, 2013; Lesaux, Lipka & Siegel, 2006; Lesaux et al., 2007). In fact, Lesaux and colleagues (2006) found the predictive relationship between verbal working memory and reading comprehension to be comparable in EAL and FLE learners. As for monolingual children, there is no evidence identifying non-verbal working memory as a unique predictor of reading comprehension in EAL children. Notwithstanding, in their meta-analysis, Jeon and Yamashita (2014) found an overall significant correlation of $r = .42$ between a variety of working memory measures and reading comprehension in language-minority learners. Comparisons between the language groups on measures of working memory have given mixed results; typically, research has demonstrated there to be no significant difference between the groups on measures of verbal working memory (Farnia & Geva, 2013; Geva & Farnia, 2012; Harrison et al., 2016; Raudszus et al., 2018). This might be explained by evidence suggesting that bilingual individuals are able to transfer their working memory skills across languages (Abu-Rabia & Siegel, 2002; Da Fontoura & Siegel, 1995). However, some studies have found monolingual learners to outperform language-minority learners at verbal working memory (e.g., Jongejan et al., 2007; Lesaux et al., 2007). This discrepancy might be explained by the linguistic demands of the specific tasks used; both studies reporting a difference between the language groups used a sentence span task demanding a good level of language comprehension. On measures of non-verbal working memory, bilingual learners have typically been found to outperform monolingual learners (e.g., Morales, Calvo & Bialystok, 2013), demonstrating the non-verbal cognitive benefits of bilingualism. Overall, despite the link between working memory and reading comprehension, language-minority learners do not seem to struggle on working memory tasks unless they have a particularly high demand on language comprehension ability and thus working memory does not seem likely to be an important factor in the lower reading comprehension levels of EAL learners.

1.3.3.2 Non-Verbal Ability

Non-verbal ability, also known as non-verbal reasoning or non-verbal IQ, refers to the ability to solve problems based on visual information using analysis and reasoning skills, and hence does not rely on any aspect of language production or comprehension. Typically, tests of non-verbal ability present sets of visual stimuli, such as matrices, to participants and require a non-verbal response such as pointing. Although non-verbal ability is theoretically unrelated to reading comprehension and is thus rarely investigated as a predictor of reading comprehension, tests of non-verbal ability are often included in studies as a control measure in order to pinpoint whether difficulties with reading comprehension lie in language or literacy weaknesses or in a more general cognitive weakness.

There is some evidence to suggest that non-verbal ability is related to reading comprehension in both EAL and FLE children (e.g., Babayiğit, 2014; Babayiğit & Shapiro, 2020; Beech & Keys, 1997); however, such studies show that typically, non-verbal ability does not uniquely contribute to reading comprehension after controlling for other skills such as decoding and language comprehension. The literature shows mixed results when comparing EAL and FLE learners on measures of non-verbal ability; some studies report there to be no significant difference between the groups (e.g., Beech & Keys, 1997; Geva & Farnia, 2012) while others report a monolingual advantage (e.g., Babayiğit, 2014; Babayiğit & Shapiro, 2020). Despite these mixed results, the fact that non-verbal ability does not seem to uniquely predict reading comprehension suggests that it does not play a significant role in the reading comprehension disadvantage observed in EAL learners.

1.4 Summary

In summary, EAL learners in England and indeed language-minority learners across the world face a disadvantage in L2 literacy, and more specifically, in reading comprehension. The literature demonstrates that reading comprehension is a complex skill with various underlying predictors. According to the SVR (Gough & Tunmer, 1986), reading comprehension broadly consists of two multi-faceted components: decoding and language comprehension. Typically, research has found that EAL and language-minority learners struggle with language comprehension skills such as vocabulary in comparison to monolingual learners, but not with decoding skills such as word reading. Thus, it appears that the reading comprehension difficulties of EAL and language-minority learners are a result of weak language comprehension skills. Given that reading is essential to general academic performance, the weaker reading comprehension abilities of EAL children are likely to permeate a variety of academic subjects, resulting in lower academic achievement in areas other than literacy. The current study aims to add to the growing body of research into the academic abilities of EAL children by assessing the linguistic abilities of EAL and FLE children in England across the course of KS2, and investigating how these influence the same cohort's academic performance in mathematics, a subject seemingly unrelated to language. Accordingly, the following chapter will review the literature surrounding how reading comprehension and its predictors relate to mathematical performance and thus how EAL and language-minority children perform in mathematics in comparison to monolingual learners.

2 Mathematical Performance in EAL and FLE Children

Interestingly, EAL children in the UK have been found to perform less well than FLE children in mathematics, although to a lesser extent than in literacy (Strand et al., 2015). This suggests that the weaknesses EAL children typically face in literacy do extend to mathematics, and warrants research into this conjecture, such as the study presented within this thesis. Strand and colleagues found that EAL children score consistently higher in mathematics assessments than they do in literacy assessments, and that the achievement gap between EAL and FLE children in mathematics narrows more quickly than the literacy gap. Nevertheless, at the ages of 5 and 7, a 7-9% achievement gap in mathematics was reported between EAL and FLE children. By age 11 this had narrowed to 2% and by age 16, EAL children actually outperformed FLE children by 0.6%. Relatively little research exists which investigates the reasons behind this initial mathematical disadvantage, despite the perhaps surprising fact that children with an academic disadvantage seemingly confined to language and literacy underperform in a domain which is viewed by the wider world to be largely unrelated to language. The magnitude and shorter duration of the mathematical disadvantage in EAL children compared to their disadvantage in literacy perhaps explains this relative lack of research. Despite this, the reasons for the initial disadvantage EAL children face in mathematics should be explored with the ultimate aim to eradicate the achievement gap entirely.

Given that the primary distinction between the EAL and FLE populations is their language background, it seems reasonable to postulate that the mathematical disadvantage faced by EAL children is, at least in part, a result of their lower English proficiency and skills such as reading comprehension and its predictors. Indeed, in their review of the literature on language and literacy skills in EAL children, Murphy and Unthiah (2015) conclude that the reading comprehension disadvantage often observed in EAL children is likely to be a reason for their lower academic achievement. Furthermore, there is evidence from national data demonstrating a link between PiE and mathematical achievement in EAL children in England. For example, Strand and Hessel (2018) found EAL mathematics achievement scores to increase with levels of PiE proficiency, as measured by the now discontinued PiE proficiency scales, in KS1, KS2 and at GCSE. By way of illustration, 23.6% of EAL children who were New to English met the expected standard in mathematics at KS1, compared to 76.1% of monolingual children. This rose to 45.8% for EAL children at the Early Acquisition level, to 73.1% for those Developing Competence, and this statistic surpassed that of the monolingual group for children with the two highest levels of PiE. Similar patterns were seen at KS2 and GCSE, with EAL children in the first three PiE levels achieving average grades of 1.9 to 3.4 in GCSE Mathematics as compared to the monolingual average of 4.5. Furthermore, Strand and Hessel found PiE to significantly account for 15.5% of the variance in KS2 mathematics scores and 13.2% of the variance in GCSE Mathematics grades (N.B. this analysis was not possible for KS1 scores because the corresponding KS1 variable was not continuous). Given that PiE predicts mathematical achievement in EAL children in England and the fact that, as discussed in detail in Section 1.1, many children classified as EAL learners in England are in fact competent or fluent in English, it follows that the mathematical achievement statistics reported by Strand and colleagues (2015) likely misrepresent EAL children with lower levels of PiE; in reality, the gap is likely to be much wider for many EAL children. This further emphasises the need for research which investigates the mathematical disadvantage that EAL children face and looks beyond the binary classification of EAL status in order to identify those most in need of mathematical support.

Taking the discussed findings into account, this chapter will explore the literature regarding the relationship between language and mathematics, the performance of EAL children on different types of mathematical task relative to FLE children and the predictors of mathematical ability, specifically mathematical WPS, in both EAL and FLE children.

2.1 The Role of Language in Mathematics

Before evidence surrounding the specific link between language and mathematics in EAL children is discussed, it is useful to consider the relationship between language and mathematics more generally. Although at first glance the two domains seem largely unrelated, language skills are essential to mathematics. A meta-analysis by Peng and colleagues (2020) found an overall moderate correlation of $r = .42$ between language and mathematics measures across 344 studies. The role of language in mathematics is very complex and thus language is linked to mathematics in several different ways. For example, language skills are important to numerical cognition itself and facilitate the retrieval of mathematical facts from memory (Peng et al., 2020). While there are aspects of numerical cognition which require no linguistic input or ability whatsoever, other aspects are inextricably linked to language. The following section will briefly discuss the role of language in two models of numerical cognition and development.

2.1.1 Language in Models of Mathematical Cognition

One model which illustrates the role of language in mathematics is the Triple Code Model (Dehaene, 1992), which states that there are three systems, or representational codes, through which numbers can be processed: the visual Arabic code (e.g., “2”), the auditory verbal code (e.g., “two”), and the analogue magnitude representation (e.g., “••”). These codes interact to drive the processing of mathematical tasks, each commanding different tasks to varying extents. Broadly speaking, the visual Arabic code drives the processing of Arabic number notation (e.g., when carrying out multidigit operations) and the auditory verbal code drives verbal mathematical tasks involving processes such as counting and fact retrieval. Dehaene explains that these two codes rely upon language skills, either verbally or through knowledge of a notation system such as the Arabic system. The third code, in contrast, has no reliance on language. The analogue magnitude representation refers to a mental number line used to perceive the numerosity of a group of objects before any verbal or visual code might be applied. The analogue magnitude representation is used in tasks involving estimation and quantification, such as subitizing. As detailed by Dehaene and researched extensively since, such abilities have been shown to exist in preverbal infants and animals, proving the absence of any dependence on language ability. As the leading model of number processing, the validity of the Triple Code Model has been supported in a wealth of literature including both behavioural and neuroimaging studies (for a review, see Siemann & Petermann, 2018). In summary, the Triple Code Model suggests that while there are preverbal aspects of numerical cognition, any mathematical tasks requiring the use of the auditory verbal or visual Arabic codes have some dependence on language ability.

The importance of language within the domain of mathematics is also highlighted in the Pathways model of mathematics development, proposed and tested by LeFevre and colleagues (2010). The Pathways model suggests that three distinct cognitive pathways contribute to both early numerical development in preschool children and to their later mathematical achievement during school; these are the linguistic, quantitative and spatial pathways. LeFevre and colleagues tested their model in a longitudinal study of children between the ages of 4 and 7 in the USA. Linguistic skills were measured using a phonological awareness task and a receptive vocabulary task, quantitative skills were measured using a subitising task in which participants were asked to judge how many objects were presented in different arrays, and spatial awareness skills were measured using a spatial span task. Regarding early numerical development, it was hypothesised that linguistic skills would predict performance on tasks requiring knowledge of the Arabic number system and that quantitative skills would predict performance on non-verbal arithmetic tasks or tasks testing magnitude comparison skills, while spatial skills would independently predict performance on both sets of tasks. Regarding later achievement on a range of mathematical measures in the third year of the study, the authors hypothesised that the three pathways would contribute differentially to each outcome measure based on its cognitive demands. The results of the study supported the model and the discussed hypotheses. Regarding early numerical skills, the study showed that the linguistic skills tested (phonological awareness and receptive vocabulary) both uniquely accounted for variance in performance on a number naming task, but did not significantly account for any variance on a non-verbal arithmetic task. Specifically, phonological awareness accounted for 30% of the variance in number naming. Regarding later mathematical achievement, linguistic scores were found to correlate significantly with all outcome measures to varying extents, most strongly with performance on a numeration subtest. This model again highlights the vital importance of language skills for both core number skills and later mathematical achievement, particularly for tasks requiring knowledge of the Arabic number system, and specifically connects phonological awareness and, to a lesser extent, vocabulary knowledge with mathematical ability.

The next section will begin to explore in more detail how different language skills contribute to performance on types of mathematical tasks; specifically, the literature surrounding the role of phonological processing in mathematics will be summarised and discussed, given that phonological skills are a key component of reading comprehension.

2.1.2 Phonological Processing and Mathematics

As evidenced in the aforementioned study by LeFevre and colleagues (2010), which identified phonological awareness as a key linguistic factor in mathematics, phonological processing skills have often been investigated in relation to mathematics. Three skills are typically thought to fall under the umbrella term of phonological processing; these are phonological awareness, phonological short-term memory and speed of lexical access. A meta-analysis by Yang and colleagues (2021), which investigated the relationship between phonological processing and maths, found a significant overall correlation of $r = .33$ between phonological processing and mathematical performance, and found phonological processing to uniquely contribute to mathematics even after controlling for executive functioning, non-verbal ability and vocabulary knowledge. Similarly, Peng and colleagues (2020) found a significant overall correlation of $r = .35$ between phonological processing and mathematics.

In particular, phonological processing skills have been shown to strongly predict performance on arithmetic tasks. These include tasks measuring the speed at which simple arithmetic problems can be correctly answered, often referred to as arithmetic fluency or arithmetic fact retrieval, or simply how accurately arithmetic problems which are somewhat more complex can be solved, typically referred to as arithmetic computation. In a longitudinal study of children aged 7 to 11 years, Hecht, Torgesen, Wagner and Rashotte (2001) found all three key aspects of phonological processing to predict growth in performance on an arithmetic computation task after controlling for prior arithmetic computation ability and general verbal ability. In fact, these three skills accounted for almost all of the association between general reading ability and arithmetic computation. In addition, Fuchs and colleagues (2005) found a phonological processing composite to predict performance on an arithmetic computation task as well as an arithmetic fluency task. Broadly, the theoretical explanation for the link between phonological processing and arithmetic ability lies in the process of retrieving verbal number codes retained in long term memory, which is vital to arithmetic computation (Robinson, Menchetti & Torgesen, 2002). To illustrate, children might solve relatively simple arithmetic problems by retrieving a number code or arithmetic fact from memory, or might utilise their knowledge of phonological number codes to calculate the answer to more difficult arithmetic problems through counting (e.g., Simmons & Singleton, 2008).

Turning to the specific roles of different phonological skills, an abundance of research has demonstrated predictive links between one or more aspects of phonological processing and arithmetic ability. Phonological awareness has widely been found to uniquely predict arithmetic computation (e.g., Amland, Lervåg & Melby-Lervåg, 2021; Bjork & Bowyer-Crane, 2013; Leather & Henry, 1994; Simmons, Singleton & Horne, 2008; Vukovic & Lesaux, 2013a; Yang & McBride, 2020). There is also some evidence that phonological awareness predicts arithmetic fluency (e.g., De Smedt, Taylor, Archibald & Ansari, 2010). Speed of lexical access, typically measured using RAN tasks, has also been found to uniquely predict both arithmetic computation (e.g., Koponen, Salmi, Eklund & Aro, 2013; Yang & McBride, 2020; Yang, McBride, Ho & Chung, 2019) and arithmetic fluency (e.g., Bull & Johnston, 1997; Koponen et al., 2016). A meta-analysis by Koponen, Georgiou, Salmi, Leskinen and Aro (2017) found a significant overall correlation of r = .37 between RAN tasks and mathematics, and an even stronger association between RAN and arithmetic ability, especially for single-digit fluency tasks. The evidence regarding the relationship between phonological memory and arithmetic ability is less clear; while some studies have found phonological memory to uniquely predict arithmetic performance (e.g., Bull & Johnston, 1997; Noël, Seron & Trovarelli, 2004), others have found phonological memory to overlap considerably with the other phonological processing skills and to therefore play no unique role in arithmetic ability (e.g., Hecht et al., 2001; Yang & McBride, 2020). Notwithstanding, a correlation between the two has been demonstrated, for example in a meta-analysis by Friso-van den Bos, van der Ven, Kroesbergen and van Luit (2013). However, Yang and colleagues (2021) found both phonological awareness and speed of lexical access to be more strongly associated with mathematical performance than phonological memory was.

Theoretically, the three skills which underlie phonological processing have been found to contribute to arithmetic ability in somewhat different ways. Specifically, research suggests that phonological awareness and phonological memory contribute to the accuracy with which individuals can solve arithmetic problems through processes such as counting. That is, in order to solve an arithmetic computation problem, individuals must encode and retain phonological representations of numbers and operators in memory while implementing mental strategies to solve the problem (e.g., Hecht et al., 2001) and thus stronger levels of phonological awareness and phonological memory will leave more cognitive capacity for calculation itself. This explains why phonological awareness, and to some extent phonological memory, has typically been found to predict performance on arithmetic computation but not arithmetic fluency tasks. In contrast, research suggests that speed of lexical access facilitates the solving of simple arithmetic problems through fact retrieval from long term memory; efficient retrieval of phonological name codes is related to efficient retrieval of arithmetic facts (e.g., Hecht, 1999) and thus speed of lexical access is strongly linked to the fluency with which individuals can solve simple arithmetic problems, more strongly predicting performance on arithmetic fluency tasks than on arithmetic computation tasks. Indeed, in their meta-analysis of 94 studies, Yang and colleagues (2021) found phonological awareness and phonological memory to be significantly more associated with mathematical computation accuracy than with mathematical fluency, whilst the opposite was true for speed of lexical access.

Further evidence for the link between phonological processing and mathematical ability comes from studies of children with reading disorders, such as dyslexia. A large body of research demonstrates that individuals with the most common form of dyslexia show a deficit in phonological processing (e.g., Bruck, 1992; Snowling, 1981; Vellutino, Fletcher, Snowling & Scanlon, 2004). More recent research has suggested that individuals with phonological dyslexia experience mathematical difficulties as a result of their phonological deficit; specifically, they struggle with arithmetic computation and related fact retrieval (e.g., Boets & De Smedt, 2010; De Smedt & Boets, 2010; Evans, Flowers, Napoliello, Olulade & Eden, 2014; Miles, Haslum & Wheeler, 2001; Simmons & Singleton, 2006, 2008). Moll, Göbel and Snowling (2015) investigated the mathematical skills of children with reading disorder and found them to struggle with mathematical tasks involving counting, calculation and number identification. Again, this demonstrates that a phonological weakness leads to difficulties with mathematical tasks requiring retention and retrieval of phonological number codes or arithmetic facts.

Overall, there is a clear link between language and mathematics, in that phonological weaknesses lead to difficulty with mathematical tasks which tap the phonological aspects of number processing. However, as discussed previously, EAL children have commonly been found to perform at approximately the same level as FLE children on measures of English phonological processing and general decoding skills (e.g., Melby-Lervåg & Lervåg, 2014), ostensibly due to the transfer of such skills across languages. This suggests that the collective mathematical disadvantage faced by EAL children in comparison to monolingual children is not due to a phonological weakness, but another reason entirely. Given that EAL children have widely been found to struggle with language comprehension skills, it stands to reason that their comprehension weaknesses cause some difficulty with mathematics; the current study aims to investigate this possibility. The following sections will discuss the existing research on the role of comprehension skills in mathematics in monolingual populations with the aim to elucidate possible reasons for the mathematical disadvantage experienced by EAL children.

2.1.3 Vocabulary Knowledge and Mathematics

As well as contributing to numerical cognition, language skills are universally essential to the learning and application of mathematics (e.g., Dale & Cuevas, 1987). As discussed by Morgan, Craig, Schütte and Wagner (2014), communication through language is fundamental to the ability to access and understand otherwise intangible mathematical concepts. These concepts can often be reified and communicated solely through language (e.g., by using words, expressions or symbols), and thus the teaching of mathematics relies largely on language. This suggests that the learning of mathematics might be mediated by aspects of an individual’s oral comprehension. Given the vital role of communication in mathematics education (e.g., Donlan, Cowan, Newton & Lloyd, 2007; Singer, Strasser & Cuadro, 2019), limited vocabulary knowledge might lead to difficulties with grasping mathematical concepts. There is evidence in the literature of an association between general vocabulary knowledge and mathematics; for example, in their meta-analysis studying the relationship between language and mathematics, Peng and colleagues (2020) found a significant overall correlation of $r = .42$ between vocabulary and mathematical measures. Vocabulary knowledge has been found to uniquely predict performance on measures of general mathematical ability or early numeracy skills (e.g., Duncan et al., 2007; LeFevre et al., 2010; Purpura & Ganley, 2014; Purpura et al., 2011) although some studies have found no unique predictive link (e.g., Foster, Anthony, Clements & Sarama, 2015). In addition, some studies have found a link between general oral language and mathematics (e.g., Hooper, Roberts, Sideris, Burchinal & Zeisel, 2010).

The investigation of the associations between vocabulary knowledge and performance on specific mathematical tasks has led to mixed results in the literature. Typically, studies have found no predictive relationship between vocabulary and arithmetic ability (e.g., Chow & Ekholm, 2019; Purpura et al., 2011). There is, however, some evidence to suggest that vocabulary knowledge, or measures of general language comprehension containing vocabulary knowledge, uniquely predicts performance on mathematical word problems which contextualise calculations using words and thus require comprehension skills to be deciphered (e.g., Fuchs et al., 2006, 2010; Purpura et al., 2011). Conversely, there is also some evidence against this predictive relationship (e.g., Foster et al., 2015). Overall, the relationship between vocabulary and mathematical performance on specific mathematical tasks is relatively under-researched and thus it is difficult to draw any clear conclusions. Nevertheless, the literature seems to suggest that vocabulary knowledge plays a role in mathematical WPS rather than arithmetic ability, and also in general numeracy skills such as number naming or counting.

While the literature regarding the link between general vocabulary knowledge and mathematics is quite mixed, somewhat less mixed results have been found when focusing specifically on the knowledge of vocabulary which is uniquely related to, or used in, mathematics. The specific language used in mathematics, and the meanings associated with it, can be referred to as the mathematics register (Cuevas, 1984). According to Dale and Cuevas (1987), the mathematics register constitutes vocabulary, syntax, semantics and discourse features, all of which need to be understood in order to become competent in mathematics. As an example, Dale and Cuevas describe the different types of vocabulary used in the mathematics register. These consist of: technical vocabulary specific to the domain of mathematics (e.g., *denominator, logarithm*), everyday words which have an alternative mathematical meaning (e.g., *product, volume*) or in fact multiple alternative mathematical meanings (e.g., *square*), complex phrases that combine mathematical concepts (e.g., *least common multiple*) and multiple words which all refer to the same concept (e.g., *plus, add, sum*), as well as mathematical symbols and everyday language. Given the prevalence of mathematical vocabulary in mathematical education and assessment, it seems likely that a limited understanding of such vocabulary might lead to difficulties in mathematics.

The predictive relationship between mathematical vocabulary and mathematical achievement has only recently begun to be researched in the literature, and thus the evidence is somewhat limited. Notwithstanding, a meta-analysis by Lin, Peng and Zeng (2021) found an overall significant correlation of $r = .49$ between mathematical vocabulary knowledge and mathematics. There is some evidence to suggest that mathematical vocabulary knowledge uniquely predicts early numeracy skills (Hornburg, Schmitt & Purpura, 2018; Purpura, Logan, Hassinger-Das & Napoli, 2017; Purpura & Reid, 2016; Toll & van Luit, 2014) and general measures of mathematics in 7- to 11-year-old children (van der Walt, 2009). In fact, it seems that mathematical vocabulary knowledge might mediate the relationship between general vocabulary knowledge and early numeracy skills; for example, Purpura and Reid found that the addition of mathematical vocabulary knowledge into their model predicting early numeracy skills rendered the contribution of general vocabulary knowledge non-significant. In this study, mathematical vocabulary knowledge uniquely accounted for 4% of the variance in early numeracy scores. This shows that mathematical vocabulary plays an important role even before children start their formal mathematics education or undertake any mathematical assessment. There is also evidence that mathematical vocabulary training improves early numeracy skills; Purpura, Napoli, Wehrspann and Gold (2017), found that 3- to 5-year-old children who had received a mathematical vocabulary intervention significantly outperformed the control group on post-test measures of early numeracy.

Notably, there are very few studies in the literature which investigate the role of mathematical vocabulary in older primary school children, and hence focus on different types of mathematical task rather than general numeracy skills. Such research has typically found mathematical vocabulary knowledge to uniquely predict performance on mathematical word problems after controlling for the contributions of general vocabulary knowledge and other skills such as working memory and numeracy (Fuchs, Fuchs, Compton, Hamlett & Wang, 2015; Peng & Lin, 2019; Xu et al., 2021). This was also found to be true across the results of 13 studies by Lin (2021) in a study employing meta-analytical structural equation modelling to investigate the predictors of WPS. However, mathematical vocabulary has not been found to predict performance on arithmetic computation tasks, despite significant positive correlations being identified between mathematical vocabulary and arithmetic computation (Forsyth & Powell, 2017; Powell, Driver, Roberts & Fall, 2017). These results echo the results of those pertaining to general vocabulary knowledge, and are also echoed in the results of a meta-analysis by Lin, Peng and Zeng (2021) which found mathematical vocabulary knowledge to correlate more strongly with mathematical WPS than with arithmetic ability. Nevertheless, further research which seeks to clarify the role of mathematical vocabulary in different types of mathematical task is warranted.

In summary, despite the recency of the research interest surrounding the role of mathematical vocabulary in mathematics, there is evidence that mathematical vocabulary plays a unique role in mathematical performance. Riccomini, Smith, Hughes and Fries (2015) summarise the role of mathematical vocabulary in mathematics and suggest strategies by which mathematical vocabulary can be taught effectively in classrooms. Overall, it seems that both general vocabulary knowledge and mathematical vocabulary knowledge are unique predictors of mathematics. Given that EAL learners have widely been found to have lower levels of general English vocabulary knowledge than FLE learners (see Section 1.3.2.1) and might thus also struggle with English mathematical vocabulary, it seems likely that weak vocabulary knowledge might partially explain the observed mathematical achievement gap between EAL and FLE learners. Accordingly, the current study will explore the roles of both general and mathematical vocabulary knowledge in EAL and FLE performance on different mathematical tasks. The following section will discuss the role of reading comprehension in mathematical performance, focusing specifically on mathematical word problems and the role of reading comprehension in the solving of such problems.

2.1.4 Mathematical Word Problems: the Role of Reading Comprehension

While there is some evidence that vocabulary knowledge, and in particular knowledge of mathematical vocabulary knowledge, uniquely predicts mathematical performance, research investigating the role of comprehension skills in mathematics has more commonly focused on the broader skill of reading comprehension, of which vocabulary is a component part (see Section 1.2.2). Research has widely suggested that reading comprehension plays an important role in mathematical WPS; evidence for this will be discussed in detail below, after a short introduction to mathematical word problems and their use in mathematics education.

Mathematical word problems can be defined as verbal descriptions of contextual problems, in which a question or multiple questions are asked and can be answered by applying mathematical operations to numerical data presented within the question (Verschaffel, Greer & De Corte, 2000). This distinguishes them from both mathematical problems presented in bare form (e.g., 7 + 8 = ?) and in verbal form (e.g., What is 7 plus 8?). In recent years, there has been a focus on contextualising arithmetic calculations within word-based problems in mathematical education systems (Adoniou & Qing, 2014). This is reflected in the current national curriculum for primary school mathematics in the UK (DfE, 2013a). As early as Year 1, children are expected to be able to "solve problems in familiar practical contexts, including using quantities", and this is extended to involve the context of monetary payments and receiving change by Year 2. The theme of contextualising mathematical problems into real-life situations continues throughout the primary curriculum, as well as across the most recent Key Stage 3 and KS4 curriculums (DfE, 2013b, 2014). Mathematical word problems also appear often in national standardised tests within the UK, such as the SATs taken in Year 2 and Year 6, and also in other countries including the USA and Australia (Trakulphadetkrai et al., 2017). The primary purpose of including word problems in mathematics education is to give children the opportunity to practice applying newly learned mathematical concepts to situations which they might encounter in real life (Verschaffel et al., 2000). Success in WPS seems to be important to later mathematical education; in a report by Hoffer, Venkataraman, Hedberg and Shagle (2007), teachers claimed that out of 15 mathematical skills, difficulties with WPS constrained students' later success in algebra the most. Furthermore, WPS ability has been found to predict later life outcomes such as employment status (e.g., Murnane, Willett, Braatz & Duhaldeborde, 2001).

Language skills have been found to correlate more strongly with WPS than with arithmetic ability (e.g., Fuchs et al., 2008; 2016; Peng et al., 2020), with Peng and colleagues finding a greater overall correlation between language and WPS (*r* = .48) than between language and arithmetic ability (*r* = .35). Indeed, mathematical word problems are perhaps the most transparent example of the role that language can play in mathematics; given that word problems contextualise mathematical problems into sentences, they require text processing and comprehension skills to enable individuals to correctly construct a mental equation which incorporates the relevant numbers from the text and which can then be solved to find the answer (Fuchs, Fuchs, Seethaler & Craddock, 2020). This is reflected in Kintsch and Greeno's (1985) dual representation model of WPS, which emphasises that both language comprehension processes and mathematical problem-solving processes are required for successful WPS. Indeed, there is evidence that children with good arithmetic computation ability can struggle with mathematical word problems, demonstrating that other skills are required for successful WPS (e.g., Cummins, Kintsch, Reusser & Weimer, 1988; Fuchs et al., 2008). The presence of this additional component of WPS alongside skills such as arithmetic computation means that mathematical word problems place greater cognitive demands on individuals than arithmetic computation tasks do. In light of this, it is not surprising that word problems cause difficulty for many children, with children across the USA having been found to score 10-30% lower on word problems than on the equivalent problems in arithmetic form on a national level (Carpenter, Corbitt, Kepner, Lindquist & Reys, 1980).

Over the years, a growing body of literature has established reading comprehension as a strong predictor of WPS. Cummins and colleagues (1988) investigated children's recall of mathematical word problems after solving them, and found that most incorrect answers were actually correct answers to miscomprehended problems. That is, mistakes made in solving the word problems stemmed largely from reading comprehension errors rather than calculation errors. Since then, many studies have echoed these results, finding reading comprehension to be a strong and unique predictor of WPS after controlling for other predictors such as arithmetic computation or word reading (e.g., Bjork & Bowyer-Crane, 2013; Björn, Aunola & Nurmi, 2016; Fuchs, Gilbert, Fuchs, Seethaler & Martin, 2018; Kyttälä & Björn, 2014; Öztürk, Akkan & Kaplan, 2020; Vilenius-Tuohimaa, Aunola & Nurmi, 2008). Some studies have shown the influence of reading comprehension to be restricted to mathematical word problems and not arithmetic computation tasks; for example, Bjork and Bowyer-Crane found that scores of reading comprehension in 6- to 7-year-old children in the UK strongly predicted performance on word problems but not on an arithmetic computation task, while both problem types were predicted by phonological awareness scores. This suggests that while the decoding components of reading comprehension are predictive of all tasks involving mathematical calculations, the language comprehension aspects might be specifically important to mathematical word problems. Indeed, the literature shows mixed results when considering the role of reading comprehension in performance on even general tests of mathematical ability, some finding a link (e.g., Grimm, 2008; Lerkkanen, Rasku-Puttonen, Aunola & Nurmi, 2005), while others did not (e.g., Imam, Abas-Mastura & Jamil, 2013).

The link between reading comprehension and WPS has also been demonstrated in studies finding children with reading comprehension difficulties to perform at a significantly lower level on mathematical word problems than children without reading difficulties (Jordan, Hanich & Kaplan, 2003; Pimperton & Nation, 2010). In addition, there is evidence that targeting reading comprehension in interventions can help to improve WPS; a study by Nicolas and Emata (2018) demonstrated that Grade 7 Filipino children (aged 12 to 13) who had received an intervention which integrated reading comprehension instruction into the teaching of WPS scored significantly higher than the control group on a post-test measure of mathematical WPS. Taking the discussed research into account, a causal link between reading comprehension and WPS is strongly suggested. In fact, some researchers assert that mathematical word problems should be considered to be as much a test of reading comprehension as of mathematical competence (e.g., Fuchs et al., 2018). This demonstrates how important language skills can be in mathematical achievement and discredits the common perception that language and mathematics are entirely unrelated domains. Indeed, the research summarised in this section has shown different aspects of language to play roles in number processing, arithmetic ability and in mathematical WPS. In light of this and the language profiles of EAL children, the following section will discuss how EAL children have been found to perform in mathematics, focusing in particular on different types of mathematical tasks.

2.2 Mathematical Performance in EAL Children

As mentioned at the beginning of this chapter, there is evidence of a modest achievement gap in mathematics between EAL and FLE children in the UK. Research comparing the overall mathematical performance of EAL and FLE learners has also found EAL learners to perform significantly worse than FLE learners (e.g., Beal, Adams & Cohen, 2010; Chang, Singh & Filer, 2009; Neville-Barton & Barton, 2005). As discussed in Section 2.1, given the role of language in mathematics and the fact that EAL children have been found to struggle with English reading comprehension and language comprehension skills, it seems likely that the mathematical disadvantage observed in EAL children is a result of these comprehension weaknesses. Rather than playing a role in numerical cognition, as decoding skills such as phonological awareness do, it seems that weak comprehension skills might limit an individual's mathematical achievement through the way in which mathematical concepts or problems are presented to them; that is, limited knowledge of vocabulary might cause difficulties with understanding a teacher's explanation of a concept, or limited reading comprehension or vocabulary skills might cause individuals to misinterpret a mathematical problem presented through words. Research has shown the relationship between language and mathematics to be similar for EAL and FLE populations (Vukovic & Lesaux, 2013b), meaning these effects of poor comprehension are likely to manifest in EAL children.

Indeed, research has suggested that standardised tests with language content often suffer from psychometric issues when taken by EAL children. Abedi (2002) investigated the performance of EAL children on standardised tests of achievement from across the USA, finding that EAL children typically performed lower on tests of reading, mathematics and science, and that achievement gaps between EAL and FLE children were larger for tests with higher language content. Abedi demonstrates that both the reliability and validity of such tests are compromised when taken by EAL children and suggests that tests purportedly assessing mathematical ability might partially function as tests of English proficiency for EAL children, thus misrepresenting their mathematical abilities. Several studies have investigated the performance of EAL children on tests of mathematical achievement through examining the levels of differential item functioning (DIF) present in various assessments. DIF statistics represent the extent to which groups of students (in this case, EAL and FLE students) differ in their probability of correctly answering each item within an assessment after controlling for their proficiency in the primary dimension that the assessment is intended to test (Camili & Shepard, 1994). Studies have identified DIF between EAL and FLE children on standardised tests of general mathematical ability (e.g., Buono & Jang, 2021; Wolf & Leon, 2009), finding that EAL children are less likely to correctly answer questions with high language content or which contain complex language such as academic or infrequent vocabulary, the passive voice or abstract language. In addition, Alt, Arizmendi and Beal (2014) found EAL children to perform significantly worse on a language-heavy standardised mathematics test but not on a language-light measure. Studies such as these add credence to the hypothesis that the mathematical achievement gap between EAL and FLE children observed in England is likely to be a consequence of a comprehension weakness and not a weakness in numerical cognition. It is, however, notable that the studies described here were all carried out in the USA or Canada; although this is beyond the scope of the current study, further research is warranted to examine levels of DIF on standardised mathematics assessments used in the UK.

DIF seems to be a particular problem for EAL children on tests consisting of or containing mathematical word problems; Martiniello (2008, 2009) detected high levels of DIF for EAL and FLE children within a mathematical WPS test. Again, DIF statistics were higher for linguistically complex items; Martiniello identified that word problems containing complex syntax such as multiple clauses or complex vocabulary such as infrequent, polysemous or culturally specific vocabulary caused particular problems for EAL children relative to FLE children. Although they did not carry out a DIF analysis, Barbu and Beal (2010) also demonstrated that EAL performance on mathematical word problems was weaker for items containing complex language. Research comparing the overall scores of language-minority and monolingual learners on mathematical tasks has typically found language-minority children to score significantly lower than their monolingual peers on WPS tasks (e.g., Abedi, 2002; Abedi & Lord, 2001; Banks, Jeddeeni & Walker, 2016; Brown, 2005; Ríordáin & O'Donoghue, 2011; Trakulphadetkrai et al., 2017; Xu et al., 2021), but to perform at the same level as their monolingual peers on measures of arithmetic ability (e.g., Abedi, 2002; Trakulphadetkrai et al., 2017; Xu et al., 2021). While much of this research was carried out in the USA, Trakulphadetkrai and colleagues compared the performance of Year 5 EAL and FLE children in England on measures of WPS and arithmetic computation, finding the EAL group to score significantly lower in WPS (with a medium effect size of partial $\eta^2 = .10$) but at the same level as the FLE group in arithmetic computation. These results are not surprising, given the literacy profiles of EAL children; that is, EAL children typically perform similarly to FLE children on measures of decoding, which have been found to predict arithmetic computation, but struggle with comprehension skills, which have been found to play an important role in mathematical WPS.

Due to the fact that issues of DIF have been found to impede the mathematical achievement of EAL children, some researchers have suggested and evaluated the effectiveness of accommodations for EAL children when completing such assessments. Based on Cognitive Load Theory (Sweller, 1988), Campbell, Davis and Adams (2007) suggest that test items containing complex language increase the cognitive resources required by EAL children to comprehend the text of a question, leaving fewer cognitive resources available for constructing a mental equation and solving the resulting problem. Some studies have investigated the effect of simplifying the language used within mathematical problems for EAL children. Several studies have found this accommodation to significantly improve EAL performance (e.g., Abedi, Hofstetter, Baker & Lord, 2001; Abedi & Lord, 2001; Kiplinger, Haug & Abedi, 2000; Rivera & Stansfield, 2001), while others have not (e.g., Abedi, Zhang & Rowe, 2020). Other accommodations which have been evaluated include providing English or bilingual dictionaries or glossaries, reading the questions aloud or allowing extra time. A meta-analysis on the effectiveness of such accommodations for EAL children was carried out by Kieffer, Lesaux, Rivera and Francis (2009). The results of the meta-analysis showed only the provision of English dictionaries or glossaries to significantly improve EAL performance, while other accommodations such as linguistic simplification were found not to be effective. In light of this evidence, it seems that while the literature is clear in showing that language-heavy standardised tests pose a difficulty to EAL children, the ways in which to effectively combat this are still unclear or highly specific to the assessment under scrutiny.

In summary, while there is relatively little research into the mathematical performance of EAL children, the existing research suggests that EAL children do suffer a modest disadvantage in mathematics compared to FLE children, and that this disadvantage is a result of their relative comprehension weakness. That is, EAL children seem to struggle with the successful comprehension of mathematical tasks containing complex language, in particular contextualised mathematical word problems, as a result of their language comprehension difficulties and this can negatively affect their performance on tests of mathematical ability. On the other hand, EAL children do not seem to struggle with arithmetic skills, performing at the same level as FLE children on arithmetic measures and often correctly calculating the answers to misinterpreted mathematical word problems. This suggests that EAL children do not have a cognitive mathematical weakness; rather, their capacity to demonstrate their full mathematical capabilities through assessment is often impeded by their limited comprehension abilities. In light of these findings, the current study aims to assess the performance of EAL children on arithmetic computation and mathematical WPS tasks and to identify the linguistic and cognitive predictors of their performance on these tasks.

2.3 The Predictors of Mathematical WPS in EAL and FLE Children

Given that EAL children have typically been found to struggle with mathematical word problems, it is pertinent to examine the predictors of successful WPS and how these apply in EAL children in order to confirm the root cause of this difficulty and how it might be combatted. With this in mind, this section will summarise the existing literature surrounding the academic, linguistic and cognitive predictors of WPS in monolingual samples, whether these skills have been found to predict WPS in EAL or other language-minority samples, and finally how EAL or language-minority learners have been found to perform on these skills in comparison to monolingual learners. Research into WPS has typically identified and investigated four key predictors; these are arithmetic computation, language, working memory and non-verbal ability (e.g., Spencer, Fuchs & Fuchs, 2020). This section will discuss each of these predictors separately, examining the roles of any subcomponents where relevant.

2.3.1 Arithmetic Computation

Many studies have shown arithmetic computation to be a unique academic predictor of WPS in monolingual children, either concurrently (e.g., Andersson, 2007; Fuchs et al., 2018; Kail & Hall, 1999; Lin, 2021) or longitudinally across a number of years (e.g., Fuchs et al., 2016; Jögi & Kikas, 2016; Spencer et al., 2020). In addition, Fuchs and Fuchs (2002) found that children with mathematical disabilities (MD) scored significantly lower on a WPS task than children without MD. This established relationship between arithmetic computation and WPS is not surprising, given that WPS requires individuals to construct a mental arithmetic equation which must then be solved in the same way as a typical arithmetic problem would. Arithmetic competence also facilitates an individual’s ability to develop such problem models (e.g., Kintsch & Greeno, 1985). It is worth noting that while arithmetic computation predicts WPS, the predictors of WPS have been shown to differ from those of arithmetic computation (e.g., Fuchs et al., 2008) and thus arithmetic computation and WPS are considered to be distinct mathematical competencies. Predictors of arithmetic computation have typically been found to include skills such as phonological skills, processing speed, attention and working memory (e.g., Fuchs et al., 2006, 2008); these skills are likely to indirectly predict WPS through arithmetic computation.

Research assessing the relationship between arithmetic ability and WPS in EAL children is scarce. However, there is some evidence that a relationship comparable to that observed in monolingual children exists between arithmetic computation and WPS in language-minority children. Kempert, Saalbach and Hardy (2011) found arithmetic computation to uniquely predict WPS in a group of language-minority children in Germany with Turkish as their L1. Similar results have been found in the USA and Canada, although these studies used measures of overall numerical ability rather than measures of arithmetic computation specifically (Foster, Anthony, Zucker & Branum-Martin, 2018; Xu et al., 2021).

While arithmetic computation seems to predict WPS in both monolingual and language-minority children, EAL children have typically been found to perform at the same level as FLE on measures of arithmetic ability and indeed on predictors of arithmetic ability such as phonological processing, as discussed in Section 2.2; for this reason, it is not likely that the WPS skills of EAL children are typically impeded by their arithmetic competence.

2.3.2 Reading Comprehension and its Subcomponents

As discussed in Section 2.1.4, reading comprehension has widely been shown to predict WPS in monolingual children by aiding understanding of verbal information in the question and thus facilitating the construction of a problem model through extraction of the relevant details and numbers. In addition to studies investigating the relationship between reading comprehension and WPS, many studies have instead examined the role of one or both of the subcomponents of reading comprehension (i.e., language comprehension and decoding) in WPS. Most commonly, studies have focused on the role of language comprehension, establishing it as a unique predictor of WPS concurrently (Fuchs et al., 2008, 2010, 2015, 2018; Lin, 2021; Trakulphadetkrai et al., 2017; Wang, Fuchs & Fuchs, 2016) as well as longitudinally (Fuchs et al., 2016; Spencer et al., 2020). A study by Fuchs and colleagues (2021) further demonstrated a causal link between language comprehension and WPS, finding a WPS intervention to be more effective when it included embedded language comprehension instruction. Other studies have focused on measures of vocabulary alone to assess comprehension ability, again finding a unique relationship with WPS (e.g., Peng & Lin, 2019; Xu et al., 2021). In addition, as discussed in Section 2.1.3, these studies, as well as that of Lin (2021), found mathematical vocabulary to uniquely explain variance in WPS performance after the contribution of general vocabulary knowledge or language comprehension. A meta-analysis by Lin, Peng and Zeng (2021) provides further evidence of a relationship between mathematical vocabulary knowledge and WPS, reporting a significant overall correlation of $r = .58$ between the two skills. These results demonstrate the potential, yet often overlooked, benefit of using mathematical vocabulary instruction to improve WPS.

There is some evidence that decoding skills also predict WPS, although decoding measures are more rarely included in studies investigating the predictors of WPS. For example, Fuchs and Fuchs (2002) found that children with comorbid MD and reading disabilities performed significantly lower on a WPS task than children with MD only. Studies investigating the predictors of WPS which have included measures of both language comprehension and decoding skills have shown mixed results; some found both aspects of reading comprehension to uniquely predict WPS (Foster et al., 2015; Fuchs et al., 2006), while others found decoding skills such as word reading to make no additional contribution to WPS after that of language comprehension (e.g., Fuchs et al., 2008;

Spencer et al., 2020). It should be noted, however, that studies investigating the predictors of WPS typically also include a measure of arithmetic ability, which is dependent on phonological decoding skills; it is therefore possible that the predictive power of decoding skills is encompassed by that of arithmetic ability, rendering the effect of decoding ability non-significant. Indeed, both studies which found decoding to make no significant contribution to WPS included a measure of arithmetic ability. It is also possible that the predictive power of word reading diminishes with age; the study by Foster and colleagues finding both components to predict WPS was carried out with a kindergarten sample, while mixed results were found in studies assessing older children. Overall, it seems that of two the subcomponents of reading comprehension, language comprehension is the more robust predictor of WPS in monolingual children.

There is some evidence in the literature that reading comprehension and its correlates predict WPS in EAL and language-minority children, although such research is scarce. Trakulphadetkrai and colleagues (2017) found reading comprehension to uniquely account for 44% of the variance in WPS ability in a sample of EAL children from the UK. Kempert and colleagues (2011) found German language comprehension ability to uniquely account for 13.4% of the variance in German WPS in Turkish language-minority children in Germany, and similarly, Xu and colleagues (2021) found receptive vocabulary to predict WPS in Canadian language-minority children. Xu and colleagues also investigated the role of mathematical vocabulary knowledge in the WPS abilities of language-minority children, but found its contribution to be non-significant after controlling for the effects of receptive vocabulary knowledge. Foster and colleagues (2018) found neither vocabulary knowledge nor phonological awareness to make a unique contribution to WPS in a group of EAL children after accounting for the effects of general numeracy ability. However, the numeracy test used incorporated several verbal components, which might explain this surprising result. In addition, a study by Méndez, Hammer, Lopez and Blair (2019) found oral comprehension skills to uniquely account for 30% of the variance in early numeracy skills in a group of Hispanic EAL children in the USA. Although this study does not pertain directly to WPS, early numeracy skills strongly predict later mathematics achievement (e.g., Aunola, Leskinen, Lerkkanen & Nurmi, 2004), and thus this study provides further evidence for the importance of language skills in the mathematical abilities of EAL learners. Overall, the limited evidence regarding the predictors of WPS in EAL children seems to suggest that reading comprehension, and particularly its language comprehension component, predicts WPS in EAL children. However, further research is needed to add credence to these results, in particular research investigating the relationship between mathematical vocabulary knowledge and WPS in EAL children.

As discussed at length in Chapter 1, there is robust evidence that EAL children perform significantly lower than FLE children on measures of reading comprehension. In particular, EAL children have been found to struggle with language comprehension in comparison to FLE children but not with decoding skills. There is also limited evidence to suggest that EAL children perform significantly lower than FLE children on measures of mathematical vocabulary knowledge

(Kazima, 2007; Powell, Berry & Tran, 2020), although Xu and colleagues (2021) found no significant difference between the groups. Overall, based on these group differences and the established predictors of WPS, it seems likely that the language comprehension abilities of EAL children are an important factor in their difficulties with mathematical WPS, while their decoding abilities are not; the current study aims to investigate this possibility.

2.3.3 Working Memory

Working memory has widely been researched in relation to mathematics and has been found to be a significant predictor of many mathematical competencies (Friso-van den Bos et al., 2013). Research has shown a relationship between working memory and WPS; for example, Peng and colleagues (2020) found a significant overall correlation between working memory and WPS of $r = .38$ across 44 studies. Working memory has also often been established in the literature as a unique predictor of WPS in monolingual samples, after controlling for a variety of other variables, both concurrently (Andersson, 2007; Fuchs et al., 2010; Lin, 2021; Swanson, 2004; Swanson & Beebe-Frankenberger, 2004; Swanson & Sachse-Lee, 2001; Trakulphadetkrai et al., 2017; Xu et al., 2021) and longitudinally (Fuchs et al., 2016). For example, Andersson found measures of working memory to together explain 14% of the variance in WPS after accounting for arithmetic computation, reading ability and non-verbal ability. However, some studies did not find working memory to make a significant contribution to WPS beyond the contributions of factors such as arithmetic computation, language and non-verbal ability (e.g., Fuchs et al., 2006; Spencer et al., 2020). In addition, it seems that measures of verbal working memory in particular are predictive of WPS (Fuchs et al., 2018; Wang et al., 2016). As explained by Kintsch and Greeno (1985), working memory aids WPS by facilitating an individual’s ability to hold their problem model in mind and integrate this with details from the question through text comprehension as well as real-world inferences.

Although working memory has been established as a predictor of WPS in monolingual samples, there is relatively little research investigating this relationship in EAL children. There is some limited evidence that working memory is a unique predictor of WPS in language-minority children (e.g., Foster et al., 2018; Xu et al., 2021). However, Trakulphadetkrai and colleagues (2017) found that the contribution of working memory to WPS in EAL children was not significant after accounting for reading comprehension; this might be because working memory is itself a predictor of reading comprehension (as discussed in Section 1.3.3.1) and thus was already accounted for in the model. Further research is warranted to determine conclusively whether the relationship between working memory and WPS is comparable in FLE and EAL populations. Despite this, as discussed in Section 1.3.3.1, FLE and EAL children seem to have comparable working memory abilities and thus working memory is not likely to be a contributing factor to the specific difficulty EAL children face in WPS.

2.3.4 Non-Verbal Ability

Another skill which has been widely linked to WPS in the literature is non-verbal ability. Peng and colleagues (2020) found an overall correlation of r = .41 between non-verbal ability and WPS across a total of 49 studies. In monolingual children, non-verbal ability has often been established as a unique predictor of WPS concurrently (Andersson, 2007; Foster et al., 2015; Fuchs et al., 2006, 2010; Fuchs et al., 2015; Tolar et al., 2012; Wang et al., 2016) and also longitudinally (Fuchs et al., 2016; Jögi & Kikas, 2016; Spencer et al., 2020). In their meta-analysis investigating the predictors of WPS, Lin (2021) found non-verbal ability to uniquely predict WPS for the older group (Grades 3-5) only; it is suggested that this might be because the measures of WPS used for the younger group (kindergarten-Grade 2) were far less complex. It is likely that this predictive relationship exists because non-verbal reasoning skills are required for the development of the problem model (Quilici & Mayer, 1996) and also facilitate the application of problem-solving strategies to the resulting model (e.g., Xin, Jitendra & Deatline-Buchman, 2005).

Very few studies exist in the literature which examine the role of non-verbal ability in WPS in EAL or language-minority children, and the limited resulting evidence is mixed; for example, while Foster and colleagues (2018) found non-verbal ability to uniquely predict WPS in EAL children alongside other linguistic and cognitive factors, this relationship became non-significant after accounting for the contribution of general numeracy skills. It is, however, likely that this measure of general numeracy skills relied itself on non-verbal ability and that non-verbal ability might have remained a significant predictor had this numeracy measure been replaced by a measure of arithmetic computation. Conversely, Kempert and colleagues (2011) found the predictive relationship between non-verbal ability and WPS in language-minority children to be non-significant after accounting for arithmetic computation and language comprehension. As for working memory, further research is warranted to elucidate the relationship between non-verbal ability and WPS in EAL children. However, given that EAL children perform at similar levels to FLE children on measures of non-verbal ability (as discussed in Section 1.3.3.2), it is unlikely that non-verbal ability is a limiting factor in their WPS ability relative to that of FLE children.

2.3.5 Summary: The Predictors of Mathematical WPS

In summary, there is substantial evidence in the literature to suggest that the four main predictors of WPS in monolingual populations are arithmetic computation, reading comprehension, working memory and non-verbal ability. While research into the predictors of WPS in EAL or other language-minority populations is relatively scarce, the existing studies seem to suggest that the predictors of WPS in EAL children are largely comparable to those in monolingual children. Amongst the four chief predictors, the literature pertaining to EAL children is the most unclear for non-verbal ability. For this reason, the role of non-verbal ability in the WPS abilities of EAL children will be assessed within the current study, and future research should ensure to do the same.

It is important to note that the vast majority of studies discussed in this section were carried out in countries other than the UK, most commonly in the USA. This emphasises the scarcity of such research from the UK and limits the applicability of the discussed literature to the UK context. In particular, the EAL population in the UK is extremely heterogeneous, while that of the USA consists largely of children whose L1 is Spanish; it is possible that EAL children from a heterogeneous population might show a different pattern of academic achievement to EAL children from a homogeneous population, whom schools are more readily equipped to support.

Very few studies exist in the literature which directly compare the predictors of WPS between monolingual and language-minority children. One such study, by Xu and colleagues (2021), was carried out in Canada with Grade 2 and 3 children, aged between 7 and 9. Approximately half of the children attended French-language schools, while the others attended English-language schools; nevertheless, both groups consisted of children whose L1 was the language of instruction as well as children for whom the language of instruction was their L2. The L1s of the language-minority children were very varied, suggesting they were part of a heterogeneous EAL population similar to that of the UK. Xu and colleagues found that receptive vocabulary, working memory and quantitative skills significantly predicted WPS in both language groups, although interestingly, receptive vocabulary and working memory were stronger predictors for the language-minority group. It might be that the weaker language comprehension skills of language-minority children also demonstrated in the study place stronger limits on their WPS ability, and that this greater reliance on language comprehension leaves fewer working memory resources for problem-solving. Xu and colleagues found mathematical vocabulary to be a significant predictor of WPS for the monolingual group only; this suggests that mathematical vocabulary might become a limiting factor to WPS only after general proficiency in the language of instruction is mastered. In addition, Xu and colleagues compared the predictors of arithmetic fluency across the language groups, finding the predictors to be similar across the groups and also that receptive vocabulary was not a significant predictor for either language group; this suggests that language comprehension skills are specific to WPS in both language-minority and monolingual children.

Only one study was found in the literature which directly compared the predictors of WPS between EAL and FLE children in the UK; Trakulphadetkrai and colleagues (2017) did so in Year 5 children from English primary schools. Trakulphadetkrai and colleagues found reading comprehension alone to significantly predict WPS in the EAL group, while language comprehension and working memory predicted WPS in the FLE group. Non-verbal ability was not included in the study, and the contribution of arithmetic ability to WPS was also not considered. Although the predictors of WPS identified in this study seem very different, both language comprehension and working memory have been shown to predict reading comprehension, and thus the predictors might actually be somewhat comparable. Although this study would have benefitted from assessing a wider range of linguistic and cognitive skills, its results demonstrate that reading comprehension is vital to the WPS skills of EAL children in the UK as well as elsewhere.

2.4 Summary

Overall, it becomes clear from examining the literature that EAL children would benefit from strong educational support to enable them to perform to the best of their ability in mathematics. The existing research on the topic suggests that the mathematics achievement gap observed between EAL and FLE children in the UK is largely a result of the language disadvantage faced by EAL children, pertaining in particular to their lower language and reading comprehension abilities. It seems that the weaknesses they experience in these two skills might lead to difficulties when learning mathematical terms, inhibiting their mathematical understanding and especially their successful completion of mathematical word problems, and thus placing them at a disadvantage when completing mathematical assessments. There is, however, very little research investigating the link between language and mathematics in EAL children specifically, meaning there is not a sufficient basis to suggest how to provide support most effectively. Further research investigating the interplay between a range of skills is required in order to fully elucidate the reasons for the mathematical disadvantage faced by EAL children. Research should confirm the reading abilities and mathematical performance of EAL children relative to those of FLE children, and compare the individual contributions of a full range of decoding, language comprehension and cognitive skills to performance on both arithmetic and word-based mathematical tasks in EAL children and FLE children. In addition, a measure of mathematical vocabulary knowledge should be included in such studies, given that previous research has suggested its importance in the mathematical education of EAL children. Research such as this is particularly needed in the UK context, as the majority of the existing research was carried out in the USA and therefore does not relate specifically to the education system and EAL population in the UK. Moreover, much of the research focuses on one age group only; for example, the only study appraising the roles of different skills in EAL mathematical performance in the UK focuses solely on Year 5 children (Trakulphadetkrai et al., 2017); carrying out a similar study over the course of multiple primary school years would provide information regarding multiple ages as well as longitudinal data which would allow the relationships between skills to be studied over time. As evidenced in the following section, the current study will address these research gaps.

2.5 The Current Study

In order to gain a full understanding of the language and mathematical profiles of EAL and FLE children in the UK, the current study aims to compare the performance of EAL and FLE children in the UK on a range of linguistic, cognitive and mathematical measures. The study also aims to explore and compare the predictors of reading comprehension, arithmetic computation and WPS ability in EAL and FLE children in the UK. The current study investigates these aims in children from English primary schools over the course of KS2, carrying out both cross-sectional and longitudinal analysis on an extensive battery of measures covering reading comprehension, vocabulary, decoding skills, working memory, non-verbal ability, arithmetic ability and WPS. Thus, the current study gives a comprehensive account of the reading and mathematical profiles of

EAL children in the UK, being one of the first studies to do so across a number of pupil cohorts and years within the UK context. The research questions of the current study are as follows:

Chapter 4 (Reading Comprehension and its Predictors: Cross-Sectional Analysis):

1. How do the linguistic and cognitive skills of EAL children compare to those of FLE children in Year 3 and Year 5?
2. Which linguistic and cognitive skills concurrently predict reading comprehension in EAL and FLE children in Year 3 and Year 5?
3. To what extent does English language use outside of school concurrently predict reading comprehension in EAL children in Year 3 and Year 5?

Chapter 5 (Mathematical Performance and its Predictors: Cross-Sectional Analysis):

4. How do the arithmetic and mathematical WPS abilities of EAL children compare to those of FLE children in Year 3 and Year 5?
5. Which cognitive, linguistic and academic skills concurrently predict arithmetic computation and mathematical WPS in EAL and FLE children in Year 3 and Year 5?

Chapter 6 (Linguistic and Mathematical Development: Longitudinal Analysis):

6. How do the linguistic abilities of EAL and FLE children change over the course of KS2?
    a. How do the developmental trajectories of reading comprehension and its subcomponents over the course of KS2 compare between EAL and FLE children?
    b. Do the rates of growth in reading comprehension and its subcomponents between Year 3 and Year 4, and between Year 5 and Year 6 differ for EAL and FLE children?
7. What are the longitudinal predictors of reading comprehension in EAL and FLE children across the course of KS2?
8. How does the mathematical performance of EAL and FLE children change over the course of KS2?
    a. How do the developmental trajectories of arithmetic ability and mathematical WPS over the course of KS2 compare between EAL and FLE children?
    b. Do the rates of growth in arithmetic ability and mathematical WPS between Year 3 and Year 4, and between Year 5 and Year 6 differ for EAL and FLE children?
9. What are the longitudinal academic, cognitive and linguistic predictors of arithmetic computation and mathematical WPS in EAL and FLE children across the course of KS2?

3 Methodology

3.1 Chapter Overview

This chapter will detail the methodology of the current study. Information will be provided regarding the design, ethical considerations and recruitment process of the study, the participating schools and sample, the measures used and the piloting of the bespoke measures, as well as the procedure and analysis strategy of the study.

3.2 Design and Recruitment

3.2.1 Overview of the Study

The current study focuses on EAL and FLE children over the course of KS2, employing a cross-sequential and longitudinal design. Two groups of children were each tested at two time points, the second (T2) being approximately 12 months after the first (T1). One group of children were in Year 3 at T1, and the other group were in Year 5 at T1. Table 3.1 presents details of the time points and the size of each group at each of the time points. In addition to this, pilot testing was carried out in April and May of 2019. Data collection for the study was carried out in primary schools in the North East of England, specifically in and around the city of Newcastle upon Tyne.

Table 3.1
Study overview

	T1 September 2019 - March 2020		T2 September 2020 - December 2020	
	Group 1 (Year 3)	Group 2 (Year 5)	Group 1 (Year 4)	Group 2 (Year 6)
N	33	39	19	23

3.2.2 The EAL Population in the North East of England

Before the recruitment process for the current study is detailed, this section will describe the EAL population in the North East of England and how it compares to the EAL population across the whole country. The participants in this study were children from primary schools situated across three local authorities in the North East: Newcastle upon Tyne, North Tyneside and South Tyneside. Of these three local authorities, Newcastle upon Tyne had the largest percentage of EAL pupils on average across its primary schools in 2019 (DfE, 2020), at 26% (8,800 pupils). North Tyneside and South Tyneside had substantially lower percentages of EAL children on average across their primary schools, with the figure standing at 5% in both North Tyneside (1,258 pupils) and South Tyneside (1,101 pupils). The proportion of EAL children in primary schools within Newcastle upon Tyne is somewhat higher than the national figure across primary schools, which currently stands at 20.9% (DfE, 2021), while the proportion of EAL children in both North Tyneside and South Tyneside is significantly lower than the national average. In a report by

Hutchinson (2018), the Newcastle upon Tyne area is shown to be among the geographical areas containing the highest concentration of schools which fall in the lowest 10% for EAL attainment across England.

The EAL population in the North East of England consists of children with a wide range of L1s, as in England as a whole. In 2012, data on the L1s of EAL children across both primary and secondary schools in each local authority in England was published (DfE, 2012). Based on this data, the 10 most common languages among EAL children in the local authority of Newcastle upon Tyne were Bengali, Urdu, Arabic, Panjabi, Czech, Chinese, Slovak, Portuguese, Polish and French, as seen in Table 3.2, which shows all L1s spoken by over 30 EAL children in Newcastle upon Tyne. In North Tyneside and South Tyneside, the most common L1s were largely the same. The most prevalent L1s of EAL children in the North East are very representative of those in the UK as a whole; the five most common across the UK in 2016 were Urdu, Panjabi, Bengali, Polish and Arabic (Hutchinson, 2018). As can be seen in Table 3.2, the population of EAL children in the North East is very varied; there is no single L1 that dominates the population, and instead many different languages are represented. Notwithstanding, South or West Asian and European languages seem to comprise the largest part of the EAL population in Newcastle upon Tyne and its surrounding local authorities. The large variety of languages in schools across Newcastle upon Tyne and indeed the whole of England makes it difficult to reliably design a study focusing on EAL children with specific L1s. Because of this, it was decided that the current study would recruit EAL children regardless of their L1, thus reflecting the heterogeneity of the EAL population.

Table 3.2
EAL pupils in Newcastle upon Tyne by most common L1s (those with > 30 speakers)

L1 of EAL pupils	EAL pupils (%)	L1 of EAL pupils	EAL pupils (%)
Bengali	18.78	Malayalam	1.10
Urdu	11.95	Spanish	1.05
Arabic	9.58	Shona	0.96
Panjabi	7.31	Romanian	0.92
Czech	3.57	Hindi	0.87
Chinese	2.82	Kurdish	0.83
Slovak	2.52	Malay	0.76
Portuguese	2.50	Serbian/Croatian/Bosnian	0.74
Polish	2.48	Tamil	0.74
French	2.45	Pashto	0.69
Persian/Farsi	1.93	Igbo	0.62
Tagalog/Filipino	1.65	Swahili	0.60
Turkish	1.17	German	0.57
Russian	1.14		

3.2.3 Recruitment

The first stage of recruitment for the current study began in February 2019. The focus of this first stage was to recruit schools to take part in the pilot study for the current project, but schools were also asked to consider taking part in the main part of the study later in the year. Two schools agreed to take part in the pilot study, and of these schools, one also agreed to participate in the main study. The second stage of recruitment took place over June and July 2019, with the sole aim of recruiting schools for the main study. During this stage, a further two schools agreed to take part. A third stage of recruitment took place in January 2020 in an attempt to gather a larger sample; this resulted in a further three schools agreeing to take part. However, data collection was cancelled entirely in one of these three schools due to the school closures caused by the COVID-19 pandemic. Overall, two schools participated in the pilot study and five schools participated in the main study. However, due to further school closures in January 2021, T2 data collection was only carried out in the three schools which were recruited in June or July 2019 and had thus participated in T1 data collection in the autumn term of 2019.

Over all three stages of recruitment, schools in the local authorities of Newcastle upon Tyne, Gateshead, North Tyneside, South Tyneside and Sunderland were contacted. Schools were identified to be invited to participate through examination of the 2017-2018 government school census information. All schools in these local authorities with an EAL cohort representing over 10% of the school population were contacted via email and invited to take part in the study. Follow-up emails were sent after approximately two weeks to any schools which had not yet responded to the invitation. All interested head teachers were invited to arrange a meeting with the researcher, held in the school, during which further details of the study were discussed and consent forms were signed if the head teacher agreed that the school would participate in the study. The school information sheet and consent form used can be found in Appendix 1.

Once consent had been given for a school to take part, the school was asked to distribute information sheets and consent forms to the families of all pupils in the target year groups (i.e., Year 3 and Year 5); these can be seen in Appendix 2. Parents were given a deadline by which to return their signed consent form, which also asked them to give demographic information about their child such as their date of birth, gender, whether or not they were in receipt of FSM, whether or not they had any Special Educational Needs and whether they were growing up with more than one language.

Once a list of potential participants with parental consent had been drawn up for each school, purposive sampling was used, by which the participants who satisfied the inclusion criteria of the study were selected to take part. In order to be included in the study, all participants were required to be in Year 3 or Year 5 in the academic year beginning in September 2019 and to have no Special Educational Needs. In addition, EAL children were required to have some level of exposure to a language other than English in their home.

After the eligible participants with parental consent had been identified, questionnaires were distributed to the parents of the eligible EAL children in order to obtain more information about the language backgrounds of their children. If these were not returned, the necessary information was instead gleaned from the participants or from their school.

3.2.4 Ethical Considerations

The current study was granted ethical approval by the Department of Education Ethics Committee at the University of York in January 2019. The study employed an opt-in approach to parental consent; that is, only children whose parents had returned a completed and signed consent form were eligible to participate in the study. Along with the consent forms, parents were sent detailed information sheets outlining the procedure, timeline and ethical considerations of the study, and care was taken to ensure that these were written in such a way as to be accessible for parents with lower levels of English proficiency. Verbal consent was also obtained from all participants at the beginning of each data collection session.

All data was fully anonymised through the use of unique participant codes, was stored securely and was accessible only to the researcher. A full Disclosure and Barring Service (DBS) check was obtained by the researcher before data collection commenced.

3.3 Participants

3.3.1 Information about the Schools

Five primary schools in the North East of England participated in the main study; these were situated in the local authorities of Newcastle upon Tyne (2), North Tyneside (1) and South Tyneside (2) and within a 12-mile radius of each other. Table 3.3 shows pupil population data for the participating schools in the 2018/2019 academic year (retrieved from: https://www.compare-school-performance.service.gov.uk) and for the pupils participating in the main study.

Table 3.3
Pupil populations of the five participating schools

	Number of pupils enrolled	% EAL	% FSM	Number of pupils recruited			
				EAL	FLE	Total	Eligible for FSM (EAL)
School 1	286	45.5	31.1	9	8	17	4 (2)
School 2	240	22.5	54.1	5	4	9	4 (2)
School 3	236	19.1	14.8	5	13	18	1 (0)
School 4	455	29.2	17.8	6	12	18	1 (0)
School 5	207	21.7	67.9	3	7	10	6 (2)

3.3.2 Participants

A total of 28 EAL children (15 Year 3, 13 Year 5) and 44 FLE children (18 Year 3, 26 Year 5) from the five schools participated in the current study at T1. Demographic information about the sample such as age and gender is presented in Table 3.4. An independent samples *t*-test revealed no significant difference in age between the EAL children (M = 92.47, SD = 3.80) and the FLE children (M = 93.11, SD = 5.56) in the younger group, $t(31) = 0.38$, $p = .706$, and likewise no significant difference in age between the EAL children (M = 116.69, SD = 4.61) and the FLE children (M = 118.65, SD = 3.76) in the older group, $t(37) = 1.42$, $p = .163$. Chi square tests were carried out in order to determine whether the two language groups differed from each other in terms of gender or eligibility for FSM within either year group. The results of these tests revealed no significant differences in gender distribution (Year 3: $\chi^2(1) = 0.04$, $p = .849$; Year 5: $\chi^2(1) = 0.06$, $p = .810$) or FSM eligibility distribution (Year 3: $\chi^2(1) = 0.01$, $p = .943$; Year 5: $\chi^2(1) = 0.09$, $p = .768$) between the two language groups. At T2, the total sample was reduced to 42 children, due in part to school closures in January 2021 and in part to attrition. Further details regarding the T2 sample are given in Section 6.2.1.

Table 3.4
Participant demographics

	T1		T2	
	Group 1 (Year 3)	Group 2 (Year 5)	Group 1 (Year 4)	Group 2 (Year 6)
N	33	39	19	23
% EAL	45.4%	33.3%	47.3%	39.1%
% FSM	27.2%	17.9%	21.1%	17.3%
% Male	51.1%	33.3%	52.6%	30.4%
Mean age in months (*SD*)	92.82 (4.78)	118.00 (4.11)	102.32 (3.11)	128.26 (3.24)

Information regarding the EAL status and L1s of the EAL children was gathered from both the children themselves and their parents or guardians through questionnaires designed for the study. The EAL children in the current study spoke a total of 12 different L1s; these were Bengali (7 children), Arabic (6), Romanian (3), Urdu (3), Spanish (2), Pashto (1), Portuguese (1), Italian (1), Punjabi (1), Greek (1), Kurdish (1) and Uzbek (1). Although the wide range of L1s present in the EAL group made it impractical to carry out any analyses separately for speakers of different L1s, the resulting group is very representative of the heterogeneous EAL population in the UK and thus allows for the results of the study to be generalised more readily to the population as a whole.

Information regarding the language abilities and typical language use of the EAL sample was also collected from the questionnaires. Regarding language proficiency when speaking, 14 (8 Y3, 6 Y5) of the 28 EAL children stated that they were equally comfortable speaking English and their L1, while 13 (7 Y3, 6 Y5) stated that they found English easier to speak and only one child (Y5) found their L1 easier to speak than English. Thirteen (7 Y3, 6 Y5) of the EAL children were able to read in their L1 as well as English, although of these, the majority (69%, 4 Y3, 5 Y5) found English easier to read. Ten (5 Y3, 5 Y5) of the EAL children were able to write in their L1 as well as English; of these, 50% (2 Y3, 3 Y5) found writing in English easier while the others found writing in their L1 easier (40%, 3 Y3, 1 Y5) or were equally comfortable writing in both languages (10%, 1 Y5). Overall, the EAL children tended to report being more comfortable using English over their L1, and the Year 5 children reported being slightly more comfortable with English than the Year 3 children did.

Of the 28 EAL children, 11 were born in the UK and thus began their UK education in Reception. The remaining 17 children had either been born elsewhere or lived in another country prior to taking part in the study, with a further three having nonetheless started their UK education in Reception. The remaining 14 children had attended school in other countries prior to moving to the UK, with three Year 3 and two Year 5 children having joined school in the UK during Year 1, one Year 3 and one Year 5 having joined during Year 2, two Year 3 and one Year 5 having joined during Year 3 and four Year 5 children having joined during Year 4. Overall, the majority of the EAL children had either started their education in England or had experienced two or more years of education in England prior to the study beginning; only 25% had experienced under two years of education in England.

Regarding use of English in the home, five (2 Y3, 3 Y5) of the 28 EAL children reported only speaking English at home, eight (5 Y3, 3 Y5) reported speaking mostly English in the home, eleven (5 Y3, 6 Y5) reported sometimes speaking English in the home and the remaining four (3 Y3, 1 Y5) reported speaking only their L1 in the home. In terms of language use outside of school more generally, on a scale from 1 (representing using only English) to 5 (representing using only their L1), the EAL children typically reported speaking their L1 more often than English with their parents (M = 3.46) and extended family members (M = 4.31) but English more often with their siblings (M = 2.07) and friends (M = 1.50). The Year 3 EAL children (M = 2.70) reported very slightly more English use outside of school than the Year 5 EAL children (M = 2.79), but these differences were not statistically significant.

3.4 Materials

The study employed a battery consisting of both existing standardised tests and tests designed by the researcher at both T1 and T2. For the purposes of the current study, scores were not converted into standardised scores when using the standardised tests. This was because the tests used had primarily or solely been normed with monolingual samples and converting scores into standard scores for such tests is not appropriate for EAL samples (Mahon & Crutchley, 2006). Raw scores were therefore used throughout the current study on all measures, as has been the practice in other UK-based studies comparing the performance of EAL and FLE children (e.g., Bowyer-Crane et al., 2017; Burgoyne et al., 2009, 2011; Hutchinson et al., 2003). Based on the research questions of the current study, some of the measures used at T1 were not repeated at T2. The tests used to measure each skill at each time point are presented in Table 3.5. Each measure will be described in detail in the proceeding section.

Table 3.5
Overview of the test battery

Skill	Measure	T1	T2
Passage Reading			
Reading Comprehension	York Assessment of Reading Comprehension (YARC)	✓	✓
Reading Accuracy	YARC	✓	✓
Reading Rate	YARC	✓	✓
Word Reading			
Non-word reading	Diagnostic Test of Word Reading Processes (DTWRP)	✓	✓
Exception word reading	DTWRP	✓	✓
Regular word reading	DTWRP	✓	✓
Phonological Skills			
Phonological Awareness	Phoneme Isolation; Comprehensive Test of Phonological Processing Second Edition (CTOPP-2)	✓	
Speed of Lexical Access	Rapid Digit Naming & Rapid Letter Naming; CTOPP-2	✓	
Phonological Memory	Memory for Digits; CTOPP-2	✓	
Vocabulary			
Receptive Vocabulary	British Picture Vocabulary Scale: 3rd Edition (BPVS3)	✓	✓
Expressive Vocabulary	Vocabulary; Wechsler Abbreviated Scale of Intelligence – Second Edition (WASI-II)	✓	✓
Mathematical Vocabulary	Bespoke task	✓	✓
Cognitive Skills			
Verbal Working Memory	Backward Digit Recall; Working Memory Test Battery for Children (WMTB-C)	✓	
Non-verbal Ability	Matrix Reasoning; WASI-II	✓	
Mathematical Skills			
Arithmetic Fluency	Addition, Addition with Carry, Subtraction, Subtraction with Carry, Multiplication; Test of Basic Arithmetic and Numeracy Skills (TOBANS)	✓	✓
Arithmetic Computation	Bespoke task	✓	✓
Mathematical WPS	Bespoke task	✓	✓

3.4.1 Standardised Measures

3.4.1.1 Passage Reading

Passage reading competency was measured using the York Assessment of Reading for Comprehension (YARC; Snowling et al., 2009). This measure was designed to be used with children aged 5 to 11, and allows separate scores of reading comprehension, reading accuracy and reading rate to be generated. Within the test, participants are asked to read some short passages aloud and to answer eight comprehension questions about each passage. In this test, each child should read a total of two passages. The first passage to be read by each child is selected based on their age. The second passage is then selected based on the participant's comprehension score for the first passage; a score of 4 or lower (out of a total of 8) means they will proceed to read the passage one level below their first passage, while a score of 5 or above means they will proceed to read the passage one level above their initial passage. In addition, administration is discontinued if participants reach a certain number of reading errors, specified in the manual, within a single passage. Reading comprehension raw scores are given as a mark out of 8 for each passage, equating to 1 point for each comprehension question answered correctly. Reading accuracy raw scores are equal to the number of reading errors made when reading each passage aloud. Reading rate raw scores are given by the time (in seconds) taken to read each passage aloud. Raw scores are then totalled and converted to "ability scores", which account for the varying difficulty levels of the passages. To allow for comparison between the two year groups, the current study followed this procedure rather than simply using the raw scores, but did not convert these ability scores into standardised scores as further instructed in the manual due to the reasons discussed above. Based on this procedure, at both T1 and T2, the younger participants read passage 3 followed by either passage 2 or 4 and the older participants read passage 5 followed by either passage 4 or 6. Form A of the test was used for the purposes of this study. Administration of the YARC was audio-recorded for each participant so that responses could be listened back to if required. The manual reports reliability scores for reading accuracy and reading rate based on the correlation (r) between scores generated from the Form A and Form B passages; reliabilities for the passages used in this study ranged between .87 and .93 for reading accuracy and between .90 and .95 for reading rate. For reading comprehension, the manual reports Cronbach's alpha estimates for each possible scored pair of passages, and for the passages used in this study these ranged between $\alpha = .71$ and $\alpha = .77$.

3.4.1.2 Word Reading

Word reading ability was measured using the Diagnostic Test of Word Reading Processes (DTWRP; Forum for Research into Language and Literacy, 2012), a word reading assessment to be used with children aged 6 to 12. This test gives scores of non-word reading, exception word reading and regular word reading. In this test, participants are presented with pages of words and asked to read them aloud one by one. The words are separated into 30 non-words, 30 exception words and 30 regular words. One point is given for each word read correctly, resulting in a total score out of 90. During the test, administration of each list of words is discontinued if the participant scores 0 on five consecutive items. Administration of the DTWRP was audio-recorded to allow for the resolution of any scoring uncertainties encountered by the researcher at the time of administration. The internal reliability of the DTWRP is reported in the manual to be α = .99.

3.4.1.3 Phonological Awareness

Phonological awareness was measured using the Phoneme Isolation subtest of the Comprehensive Test of Phonological Processing – Second Edition (CTOPP-2; Wagner, Torgesen, Rashotte & Pearson, 2013), a test of phonological skills for use with individuals aged 4 to 24. In this subtest, the participant is asked to name certain sounds (phonemes) within a series of words. For example, one item on the test reads "What is the middle sound in the word *not*?". The items are split into two sections, each containing 16 items; the first set of items consists of words made up of three phonemes and the second set of items consists of words made up of four or five phonemes. Guidance and feedback are given for the first seven items in each section, following the instructions given in the manual. The test is discontinued immediately if the participant gives three consecutive wrong answers and is not scored at all if the participant cannot answer any of the first three items after receiving feedback. Participants score 1 point for each correct answer, giving them a total score out of a possible 32. The CTOPP-2 manual reports this subtest to have internal reliability of .88 and test-retest reliability of .83.

3.4.1.4 Speed of Lexical Access

Speed of Lexical Access was measured using the Rapid Digit Naming and Rapid Letter Naming subtests of the CTOPP-2 (Wagner et al., 2013). In the Rapid Digit Naming subtest, participants are required to name all digits in a series presented to them visually as quickly as they can. They are given a chance to practice on a separate series of six digits to begin with, and then are asked to read out the full series of 36 digits as soon as it is presented to them following the practice section of the test. The score given for this subtest is the number of seconds taken for them to name all 36 digits. The test is not scored if the participant cannot name all six practice items correctly after feedback, or if four or more errors are made when naming the test items. The procedure and scoring rules for the Rapid Letter Naming subtest are identical those of the Rapid Digit Naming subtest, but with letters being presented to the participant rather than digits. Administration of these subtests was audio-recorded so that the time taken and the errors made could be checked again after the session if necessary, given the rapid nature of the tests. For the purposes of the current study, a total RAN score was calculated for each participant, equal to the total time taken to name both the digits and the letters. The CTOPP-2 manual reports the Rapid Digit Naming subtest to have internal reliability of .87 and test-retest reliability of .88, and the Rapid Letter Naming subtest to have internal reliability of .85 and test-retest reliability of .91.

3.4.1.5 Phonological Memory

Phonological memory was tested using the Memory for Digits subtest of the CTOPP-2 (Wagner et al., 2013). In this subtest, the researcher reads out a series of sets of digits and participants are asked to recall each set of digits after hearing it once only. They are given four practice sets, for which feedback is given, after which items are administered in order without feedback. The first three test items consist of only two digits and then the span length increases by one after every three items, to a maximum of nine digits. A score of 1 is given for each correctly recalled span, resulting in a score out of a possible 28. As with the Phoneme Isolation subtest, administration is discontinued immediately after three consecutive scores of 0. This subtest has internal reliability of .81 and test-retest reliability of .83 as reported by the manual.

3.4.1.6 Receptive Vocabulary

Receptive vocabulary knowledge was measured using the British Picture Vocabulary Scale: 3rd Edition (BPVS3; Dunn, Dunn & Styles, 2009), a receptive vocabulary assessment designed to be used with children aged 3 to 16. In this test, participants are presented orally with a series of words by the researcher and are required to indicate which of a possible four pictures for each word best represents the word’s meaning. Items are presented in 14 sets of 12, and each set must be administered fully once started. Two training items are administered before starting the test to ensure understanding of the task. A recommended starting point based on the age of each participant is given, but a reverse rule applies if the participant makes more than one error in their first set. If this is the case, the test is administered in reverse until a set is reached for which the participant makes no more than one error (the “basal” set), after which normal administration is resumed. Administration is discontinued if the participant makes eight or more errors within a single set. Participants receive a score of 1 for correct answers (and all items prior to the basal set) and 0 for incorrect answers, giving them a total out of a possible 168. The process undertaken by the authors of the BPVS3 to determine the reliability of the test is not discussed here due to its complexity, but is detailed in the manual.

3.4.1.7 Expressive Vocabulary

Expressive vocabulary knowledge was measured using the Vocabulary subtest of the Wechsler Abbreviated Scale of Intelligence – Second Edition (WASI-II; Wechsler, 1999). The WASI-II was designed for use with individuals between the ages of 6 and 90. In this test, participants are presented with a series of words and are asked to define each word. Consequently, they are given a score of 0, 1 or 2 based on the accuracy of their answer. Participants aged 8 or under have the words presented to them orally only, while participants aged 9 or over have the words presented to them both orally and visually (i.e., in written form). Guidelines to assist with scoring the definition of each word given by the participant are included in the manual; these guidelines give example answers for each word, and can be referred to during administration. This test was also audio-recorded, so that the participants’ answers could be listened back to at a later time if the researcher could not make immediate scoring decisions for some items. All participants begin on Item 4 of the test, and if the participant does not obtain the maximum score on either Item 4 or Item 5, the preceding items are administered in reverse until the participant receives the full score on two consecutive items. After this, normal administration is resumed. Administration of the test is discontinued if the participant scores 0 on three consecutive items. The test consists of a total of 31 items, however for participants between 7 and 11 years of age (which, for the purposes of the current study, was all participants), administration is stopped after Item 25 if the discontinuation rule was not triggered earlier in the test. A raw score is then calculated by totalling the scores achieved by each participant (including 1 point for each of Items 1-3 if the reverse rule was not triggered), resulting in a score out of a possible 47. This subtest is highly reliable, with the WASI-II manual reporting test-retest reliability of .92 and split-half reliability of .91.

3.4.1.8 Verbal Working Memory

Verbal working memory was assessed using the Backward Digit Recall subtest of the Working Memory Test Battery for Children (WMTB-C; Pickering & Gathercole, 2001), an assessment of working memory to be used with children aged 5 to 15. In this subtest, participants have multiple sets of digits read aloud to them by the researcher and are required to recall each set of digits in reverse order. The participant is permitted to hear each set of digits once only. The sets of digits are presented in six blocks of six items which increase in span length, starting with six items consisting of two digits only, and ending with six items consisting of seven digits each. Administration begins with four practice items, after which testing begins with the first block. During administration, if a participant answers four items in a block correctly, any remaining items in that block are omitted (and recorded as correctly answered) and the next block is administered. Administration is discontinued if the participant makes three errors within one block. Each correct response awards 1 point, resulting in a score out of a possible 36. The test-retest reliability of this subtest is reported to be .53 in the WMTB-C manual.

3.4.1.9 Non-Verbal Ability

Non-verbal ability was measured using the Matrix Reasoning subtest of the WASI-II (Wechsler, 1999). In this test, participants are presented visually with incomplete matrices or series of increasing difficulty and are asked to select the one option out of a possible four which completes each matrix or series. A score of 1 is given for each correct answer, and a score of 0 is given for each incorrect answer. Two sample items are administered to all participants to ensure they understand the task, and they are given corrective feedback on these items if necessary. Following this, the items are administered in order, with 6- to 8-year-olds starting at Item 1 and participants over 8 years of age starting at Item 4. In the latter case, a reverse rule applies, stating that if a participant scores 0 on either Item 4 or Item 5, the preceding items are administered in reverse order until two consecutive scores of 1 are achieved, after which normal administration resumes. Administration is discontinued if the participant scores 0 on three consecutive items. There are a total of 30 items in this subtest, however administration with participants between the ages of 6 and 8 should be discontinued after Item 24 under all circumstances. The raw score for each participant is then calculated by totalling the number of items they answered correctly (including points for Items 1-3 for participants over the age of 8 if the reverse rule was not triggered), resulting in a score out of a possible 24 for the participants aged 6 to 8, and 30 for the participants aged 9 and over. This subtest has test-retest reliability of .81 and split-half reliability of .87, as reported by the WASI-II manual.

3.4.1.10 Arithmetic Fluency

A standardised measure of arithmetic fluency was used in this study; this was the Test of Basic Arithmetic & Numeracy Skills (TOBANS; Brigstocke, Moll & Hulme, 2016), a test designed for use with 7- to 11-year-old children. Only the five subtests required to calculate a composite score for arithmetic fluency were administered; these were Addition, Addition with carry, Subtraction, Subtraction with carry and Multiplication. In these tests, participants are required to complete as many questions in the given category as possible within a strict time limit of 60 seconds. These problems are presented to them on paper and are to be solved mentally, in the order given. Between 60 and 120 questions are presented in each subtest, in order to avoid the ceiling effect. For each subtest, participants are given a score equal to the number of questions they answered correctly within the time limit. Any skipped questions are not counted, and scoring is discontinued if the participant did not attempt three or more consecutive questions, in order to prevent the participants from answering questions selectively. After each participant completed the five subtests, their raw scores were summed to give an overall measure of arithmetic fluency. The test-retest reliability reported in the manual is .97 for this arithmetic fluency composite, and the reliability scores for the individual subtests range between .85 and .93.

3.4.2 Researcher-Devised Tasks

A number of bespoke questionnaires or tasks were created or adapted by the researcher for use in the current study. This section will detail these bespoke measures and how they were designed.

3.4.2.1 Background Questionnaires

Firstly, a questionnaire for completion by the parents or guardians of all EAL participants in order to gather details of their language backgrounds was adapted by the researcher, for use in the current study, from that used and designed by Smith (2019). This questionnaire was distributed on paper to the parents of all EAL participants after they had given consent for their child to take part in the study. In the questionnaire, the parents were asked 12 questions regarding the languages they themselves speak and to what degree, the languages their child speaks and to what degree, where their child was born and whether their child attended an English-speaking nursery, and how often their child uses each language when talking to specific members of their family or engaging in various activities at home. In anticipation of a low response rate, a separate version of the questionnaire was adapted from an additional version developed by Smith, to be administered to the EAL participants themselves. Within the current study, this was done during each EAL participant's first data collection session. This brief questionnaire, consisting of 12 short questions, asked the same questions regarding the child's background and language use habits but did not include questions about their parents' language proficiency. The parent version of the questionnaire can be found in Appendix 3 and the child questionnaire can be found in Appendix 4. Under half of the parent questionnaires were returned (39%), so the child questionnaires were used in further analysis, although the parent versions that were returned were used to verify the corresponding children's responses.

A second questionnaire was designed by the researcher for use at T2, after the school closures caused by the COVID-19 pandemic. This questionnaire was designed to gather information regarding the experiences of all participants during the school closures and the amount of home-schooling they typically engaged in between March and July 2020, in order to account for this when analysing the longitudinal data due to be collected at T2 and to investigate the effect that the school closures may have had on the academic performance of the sample. Again, the researcher designed both a parent and a child version of the questionnaire, in case of a low response rate from parents. The parent version was designed as an online questionnaire to avoid paper copies passing between the researcher, the school and the parents during the pandemic, while the child version was designed to be administered using pen and paper during the T2 data collection sessions. The questionnaires asked questions regarding whether the participants attended school during the lockdown, the activities they engaged in at home, how they found returning to school in the autumn and details about their home learning experience such as how often they engaged in schoolwork at home, with whom, and what technology they had access to. The parent questionnaire included a total of 24 questions and can be found in Appendix 5, while the child questionnaire included a total of 16 questions and can be found in Appendix 6. As with the language background questionnaires, the parent response rate was low (33%), so again the child versions were used in all analyses and the completed parent versions were used only to verify information given by the relevant children.

3.4.2.2 Bespoke Mathematical Tasks

In addition to the questionnaires, several bespoke mathematical tasks were designed by the researcher for use in the current study. Firstly, two parallel mathematical tasks were designed to test the performance of the participants on arithmetic problems and mathematical word problems respectively. The items in both tasks contained the same numeric calculations, the difference being that the arithmetic computation task presented them simply as number sentences to be completed, for example "8 x 11 = _", while the word problem task embedded the calculations into mathematical word problems, such as "Daniel reads 8 books every week. How many books will he read in 11 weeks?" These tasks were designed so that a direct comparison could be made between the participants' arithmetic computation skills and their WPS skills, given that the calculations involved did not differ at all; in effect, the tasks allowed the researcher to determine whether contextualising problems through language had an impact on performance. The task design was based on that used by Bjork and Bowyer-Crane (2013) to investigate the predictors of arithmetic computation and WPS using similar parallel tasks; these were, however, designed for use with Year 2 children and thus were not suitable for the current study. Instead, the researcher created two new sets of parallel tasks, one to be used by the Year 3-4 group and the other to be used by the Year 5-6 group. This was done using the most recent national curriculum as a guide (DfE, 2013). The tasks were designed to contain an approximately even split of questions using each of the four basic mathematical operations, and started to introduce concepts such as money, time, fractions and decimals for the older year groups, in line with the curriculum. The word problems were written to mimic the structure of the arithmetic problems as much as possible, and all numbers were written in Arabic digit form. The problems used only simple vocabulary that would be familiar to children of this age range, and situations that would also be familiar to the children, such as school-related activities or buying items from a shop. The preliminary version of each task consisted of 20 items. After the measures had been piloted, they were each reduced to 15 items; this will be explained in more detail in the proceeding section. These tasks were completed by the participants using pen and paper, and participants were given an upper limit of 10 minutes to complete the arithmetic computation task, and 15 minutes to complete the WPS task. Participants were permitted to use written or visual methods to help them determine their answers if desired. Given that the tasks contained the same numerical calculations, the tasks were completed in different data collection sessions which were at least one week apart. Participants were given a score out of 15 for each task. In order to allow for comparison between the age groups, a further 15 points were added to the scores of all participants in the Year 5-6 group, based on the assumption that they would achieve full marks on the Year 3-4 version. The internal reliabilities of the bespoke tasks were calculated using Cronbach's alpha. The alpha values for the parallel tasks were $\alpha = .82$ for the Year 3-4 arithmetic computation task, $\alpha = .85$ for the Year 3-4 WPS task, $\alpha = .88$ for the Year 5-6 arithmetic computation task and $\alpha = .82$ for the Year 5-6 WPS task, showing the parallel tasks to be very reliable. The final versions of these tasks can be found in Appendices 7 and 8.

Secondly, a measure of mathematical vocabulary knowledge was designed by the researcher for the study. The decision was made to create a bespoke measure because no UK-specific existing measure of mathematical vocabulary could be found. Again, two versions of the task were created to be used by the two year groups, testing words which the national curriculum (DfE, 2013) states that children should recognise and understand by the time they reach the corresponding school years. The mathematical vocabulary tasks each consisted of 15 multiple-choice questions testing the participants' understanding of a word used in mathematics. Each item on these tasks had four possible answers, and the participants were asked to simply state the answer they believed to be correct. A multiple-choice format has been used in other researcher-designed measures of mathematical vocabulary (e.g., Hughes, Powell & Lee, 2020; Powell et al., 2017; Powell & Nelson, 2017). The items on these tasks used a variety of formats while still all having four possible answers; some required the participants to correctly complete a sentence, some were simply questions to be answered, and some questions referred to an accompanying image illustrating a word or concept. The preliminary versions of each task consisted of 20 or 22 items. Again, each was reduced to 15 items after the measures had been piloted. The task was presented to the participants on paper, and in addition, each question and possible answer was read aloud to the participant by the researcher to ensure that reading difficulties did not impede any participant's comprehension of the questions. Again, participants were given a score out of 15 for the task, and a further 15 points were added to the scores of all Year 5 and 6 children to allow comparison between the groups. The internal reliabilities of the mathematical vocabulary tasks were found to be $\alpha = .64$ for the Year 3-4 task and $\alpha = .74$ for the Year 5-6 task, showing the tasks to have acceptable levels of reliability. The final versions of these tasks can be found in Appendix 9.

3.5 Pilot Study

In April and May of 2019, the preliminary versions of the bespoke mathematical measures for the Year 3-4 group and the Year 5-6 group were piloted in two primary schools, having been designed by the researcher in the preceding months. Although 20 or 22 items were written for each measure, the measures were designed to eventually consist of only 15 items, given that Bjork and Bowyer-Crane (2013) showed this to be an appropriate length for such tasks. The pilot study aimed to test the efficacy of each item in the tasks in order to determine which 15 items should be included in the final version of each measure, and to calculate the internal reliability of each measure. The pilot study was carried out with Year 3 and Year 5 children during the summer term of the academic year, theoretically approximately halfway between T1 and T2 of the main study. This meant that the level of mathematical education that the pilot study sample had experienced fell approximately halfway between the levels that the eventual main sample groups would have experienced at the two time points. The pilot study utilised the same recruitment and sampling strategies as the main study.

3.5.1 Method

3.5.1.1 Participants

The participants in the pilot study came from two primary schools. One school was situated in the local authority of South Tyneside, and also participated in the main study (School 1), while the other school was situated in Newcastle-upon-Tyne, and did not go on to participate in the main study. Information regarding the pupil populations of the two schools (retrieved from https://www.compare-school-performance.service.gov.uk) is presented in Table 3.6.

Table 3.6
Pupil populations of the two pilot schools

	Number of pupils enrolled	% EAL	% FSM	Number of pupils recruited for pilot study			
				EAL	FLE	Total	Eligible for FSM (EAL)

School A (main study School 1)	286	45.5	31.1	1	6	7	1 (0)
School B	418	16.3	12.2	8	7	15	0 (0)

A total of 9 EAL children (7 Year 3, 2 Year 5) and 13 FLE children (6 Year 3, 7 Year 5) participated in the pilot study. Of the participants, 12 were female (9 Year 3, 3 Year 5) and 10 were male (4 Year 3, 6 Year 5). The mean (*SD*) age in months of the Year 3 group was 98.54 (4.70) and the mean age in months of the Year 5 group was 121.22 (4.18). As in the main study, the EAL children in the pilot sample spoke a variety of L1s; these were Arabic (3 children), Dutch (1), Italian (1), Urdu (1), Japanese (1), Punjabi (1) and Malayalam (1).

3.5.1.2 Measures

The measures used in the pilot study were the preliminary versions of the bespoke mathematical tasks mentioned above: the parallel arithmetic computation and WPS tasks and the mathematical vocabulary task. In addition, both versions of the language background questionnaire were administered to the participants and their parents respectively.

3.5.1.3 Procedure

The pilot study involved one single session with each participating child, carried out in a quiet room in their school during school hours. The children were seen individually, and each session lasted approximately 30 minutes, with some lasting up to 45 minutes. If the participant was classified as EAL, the sessions started with the researcher briefly interviewing the participant about their language background in order to complete the language background questionnaire. Following this, or to begin the sessions with FLE children, the participants were given the first of the two parallel mathematical tasks. Counterbalancing was used to avoid any order effects, meaning that some participants started with the arithmetic computation task, and some with the WPS task. After completion of the first mathematical task, the participants were asked to complete the mathematical vocabulary task for their year group. Finally, participants completed the other of the two parallel tasks. The mathematical vocabulary task was completed between the two parallel tasks in an attempt to prevent participants recognising that the same calculations were required in the two mathematical tasks, and hence answering them from memory rather than calculating the answers for a second time. At the end of each session, the participants were offered a sticker as a token of appreciation, and then taken back to their classrooms.

3.5.1.4 Analysis Strategy

Participant responses were recorded item by item, in order to allow analysis of performance on each item and the calculation of the internal reliability of each measure. Internal reliability was assessed using Cronbach's alpha. The Classical Test Theory method of item analysis, as described by McAlpine (2002) was used on the six piloted measures in order to analyse the efficacy of each item on each measure. This method utilises two statistics in order to determine the efficacy of each item: a measure of Item Facility and a measure of Item Discrimination. Item Facility refers to the difficulty of each item; that is, the proportion of the total sample that answered the question correctly. This statistic is calculated by dividing the number of correct answers by the total sample size, and thus ranges between 0 and 1. McAlpine suggests excluding items which have an Item Facility value lower than 0.15 or higher than 0.85, so that no items are too difficult or too easy. Item Discrimination is the degree to which success on each item corresponds to overall performance on the test, and ranges between -1 and 1. Item Discrimination compares the scores for each item of the highest-scoring 27% of the sample and the lowest-scoring 27% of the sample, and is calculated by subtracting the number of correct answers in the low-scoring group from the number of correct answers in the high-scoring group and dividing this answer by the number of participants in these groups. According to Ebel (1954), items with an Item Discrimination value below 0.2 are weak and should be excluded, with negative values being particularly problematic, and items with an Item Discrimination value of over 0.4 should be regarded as strong. These two statistics were calculated for each item on each of the piloted tests in order to inform decisions about item exclusion. The researcher employed a strategy by which all items which were eligible for exclusion based on both statistics were excluded or at least modified. Some others were also excluded or modified to meet the required test length based on one of the two statistics and on researcher judgement through experience from the pilot study. In general, items with low facility scores were chosen to be excluded over items with high facility scores, given that due to the multiple-choice nature of the questions, some correct answers were given by participants simply guessing. In addition, when excluding one item from the arithmetic computation task or WPS task for a given year group, it was necessary to exclude the corresponding item from the other of the two tasks for the same year group in order to uphold the parallel nature of the tasks.

As well as recording participant responses item by item, participants were also given an overall score for arithmetic computation, mathematical WPS and mathematical vocabulary. For arithmetic computation and WPS, this was equal to their score out of 20 on the relevant tasks. For mathematical vocabulary, the raw scores were converted to percentages to allow for easier comparison between the year groups, given that the preliminary mathematical vocabulary tasks were of two different lengths. This process allowed the researcher to generate exploratory descriptive statistics to give a preliminary indication of how the two language groups compared on these skills, although no inferential tests were performed due to the small sample sizes, and to determine the intercorrelations between scores.

3.5.2 Results

3.5.2.1 Year 3-4 Arithmetic Computation and WPS Tasks

The preliminary versions of the Year 3-4 arithmetic computation and WPS tasks, which can be found in Appendix 10, both contained 20 items, meaning five items were to be excluded. The facility and discrimination values for the items on the Year 3-4 arithmetic computation task and the corresponding items on the Year 3-4 WPS task are shown in Table 3.7. Values indicating that the item should be removed based on the recommendations by Ebel (1954) are marked with an asterisk.

On the Year 3-4 arithmetic computation task, four items were identified for immediate exclusion based on their facility and discrimination values: Items 2, 4, 5 and 12. On the Year 3-4 WPS task, only Items 1 and 14 were identified for immediate exclusion, and these corresponded to Items 5 and 2 on the arithmetic computation task. In order to ensure that the two tasks contained the same calculations in their questions, Items 8 and 11 from the WPS task, which corresponded to Items 4 and 12 on the arithmetic computation task, were also excluded.

Table 3.7
Item Facility and Discrimination values; Year 3-4 Arithmetic Computation and WPS tasks

Item (Arithmetic Computation Task)	Facility	Discrimination	Equivalent Item (WPS Task)	Facility	Discrimination
1	.23	.75	10	.36	1.00
2	.92*	.00*	14	1.00*	.00*
3	.62	1.00	20	.55	1.00
4	1.00*	.00*	8	.64	1.00
5	1.00*	.00*	1	1.00*	.00*
6	.77	.50	13	.80	.66
7	.77	.00*	19	.55	1.00
8	.46	1.00	7	.45	1.00
9	.31	.50	5	.27	.66
10	.69	.75	17	.70	.33
11	.69	.75	4	.64	.33
12	1.00*	.00*	11	.91*	.33
13	.77	.50	6	.82	-.33*
14	.92*	.25	2	.82	.66
15	.23	.75	16	.30	.66
16	.69	1.00	15	.40	1.00
17	.31	1.00	18	.45	1.00
18	.69	.25	9	.64	.66
19	.69	.75	12	.80	.66
20	.92*	.25	3	.73	.66

Note. * indicates item is recommended for removal

It was decided that the final item to be excluded would be an item that the sample found relatively difficult, since the other items to be excluded were all items of high facility. It was also decided that the final item to be excluded should be a subtraction or division problem, to keep the proportions of questions using different mathematical operations approximately equal. Item 1 on the arithmetic computation task (corresponding to Item 10 on the WPS task) was chosen to be excluded, due to its low facility score on both tasks.

The calculations in Items 7, 14 and 20 on the arithmetic computation task and their counterparts on the WPS task were also modified to be made slightly more difficult, and Items 8, 15 and 17 and their counterparts were modified to be made slightly easier. In addition, the wording or structure of some items (4, 5, 13, 18 and 20) on the WPS task was modified to make the question slightly simpler or to ensure that the numbers were presented in the same order on both tasks. The word "change" was also replaced in Item 5, due to being a word tested on the Year 3-4 mathematical vocabulary task.

Internal reliabilities of the tasks were calculated for the pilot data using Cronbach's alpha; before the removal of any items this was found to be $\alpha = .87$ for the Year 3-4 arithmetic computation task and $\alpha = .88$ for the Year 3-4 WPS task. After the removal of the selected items, the arithmetic computation task showed internal reliability of $\alpha = .88$ and the word task showed internal reliability of $\alpha = .86$ based on the pilot data.

3.5.2.2 Year 3-4 Mathematical Vocabulary Task

The preliminary Year 3-4 mathematical vocabulary task, which can be found in Appendix 11, contained 22 items, meaning seven were to be excluded. Table 3.8 shows the facility and discrimination values for this task. On this task, three items were identified for immediate exclusion; these were Items 9, 15 and 16. Item 21 was chosen to be excluded due to its low facility score. Two other items (Items 3 and 11) were excluded based on their discrimination scores and the fact that they tested words which were mostly unknown to the participants, meaning most correct answers were guesses. The final item to be excluded was Item 8; this item had a high facility value, and it was also noted by the researcher that the one participant who answered this item incorrectly only did so because they mistook the picture of dominoes used in the question for dice, which was also an answer option.

In addition, it was decided that Items 10 and 18 would also be excluded from the task because they caused some confusion for most participants. Two new items were written for the task to replace these. In addition, the wording of Item 7 was modified slightly due to a common need to explain the question further during the pilot study.

The internal reliability of the Year 3-4 mathematical vocabulary task before item removal was found to be $\alpha = .65$. After the items were removed, the internal reliability remained at $\alpha = .65$.

Table 3.8
Item Facility and Discrimination values; Year 3-4 Mathematical Vocabulary task

Item	Facility	Discrimination	Item	Facility	Discrimination
1	.62	.25	12	.69	.50
2	.92*	.25	13	.62	.50
3	.31	.00*	14	.62	.50
4	.23	.50	15	1.00*	.00*
5	.54	.75	16	1.00*	.00*
6	.85	.50	17	.92*	.25
7	.77	.50	18	.62	.75
8	.92*	.25	19	.92*	.25
9	.92*	.00*	20	.62	.00*
10	.69	.25	21	.08*	.25
11	.31	.00*	22	.69	.50

Note. * indicates item is recommended for removal

3.5.2.3 Year 5-6 Arithmetic Computation and WPS Tasks

The preliminary Year 5-6 parallel mathematical tasks, which can be found in Appendix 12, both contained 20 items, meaning five items were to be excluded. The facility and discrimination values for these tasks are shown in Table 3.9.

Ten items were identified for exclusion based on their facility and discrimination values on both of the Year 5-6 parallel tasks, all of which were answered correctly by all participants. Of these, nine corresponded to the same calculation problem, therefore these nine items were considered for exclusion. Of these nine items, five were excluded from the task (Items 8, 10, 12, 13 and 19 on the arithmetic computation task, corresponding to Items 4, 9, 8, 14 and 3 on the WPS task) and four were modified or replaced to be made more difficult (Items 4, 5, 7 and 17 on the arithmetic computation task, corresponding to Items 16, 6, 19 and 17 on the WPS task). Care was taken to ensure that the remaining items contained an approximately equal spread of mathematical operations and that the measure included items requiring understanding of the concepts of money, time, decimals and fractions, all of which are common in assessments taken at this age. To this end, Item 1 on the arithmetic computation task and its equivalent on the WPS task (Item 18) were modified to involve money.

As with the Year 3-4 WPS task, the wording or structure of some items (Items 1, 12 and 13) on the Year 5-6 WPS task was modified to either simplify the structure of the question or to ensure that the numbers were presented to the participants in the same order on both tasks.

The internal reliability of the Year 5-6 arithmetic computation task was found to be $\alpha = .56$, while the internal reliability of the Year 5-6 WPS task was found to be $\alpha = .88$. On removal of the selected items, the internal reliability of the arithmetic computation task increased slightly to α = .57, and the internal reliability of the WPS task decreased slightly to α = .87.

Table 3.9
Item Facility and Discrimination values; Year 5-6 Arithmetic Computation and WPS tasks

Item (Arithmetic Computation Task)	Facility	Discrimination	Equivalent Item (WPS Task)	Facility	Discrimination
1	.88*	.50	18	1.00*	.00*
2	.63	.00*	1	.11*	.50
3	.50	1.00	7	.44	1.00
4	1.00*	.00*	16	1.00*	.00*
5	1.00*	.00*	6	1.00*	.00*
6	.88*	.50	10	.78	1.00
7	.88*	.00*	19	1.00*	.00*
8	1.00*	.00*	4	.89*	.00*
9	.88*	.00*	2	.78	.50
10	1.00*	.00*	9	1.00*	.00*
11	.63	1.00	12	.75	.50
12	1.00*	.00*	8	1.00*	.00*
13	1.00*	.00*	14	.88*	.00*
14	.63	.00*	5	.78	.00*
15	.88*	.50	11	.78	.50
16	.50	1.00	20	.75	1.00
17	.88*	-.50*	17	.88*	.00*
18	.75	.50	13	.88*	.50
19	1.00*	.00*	3	1.00*	.00*
20	.75	1.00	15	.88*	.50

Note. * indicates item is recommended for removal

3.5.2.4 Year 5-6 Mathematical Vocabulary Task

The preliminary Year 5-6 mathematical vocabulary task, which can be found in Appendix 13, consisted of 20 items, meaning five items were to be excluded. Table 3.10 shows the facility and discrimination values for each item.

Eight items were identified for immediate exclusion based on their facility and discrimination values. Of these eight items, five were removed from the task (Items 1, 9 ,11, 12 and 14) and three were modified to include more challenging answer options (Items 4, 8 and 17). The latter three items were chosen to be modified rather than removed due to the researcher noting that they posed more difficulty to participants than the former five despite all participants eventually reaching the right answer, either through deduction or guesswork. The wording of one answer option for Item 5 was also modified due to none of the participants being familiar with the word “integer”; this was therefore changed to “whole number”.

It was also decided that two further items would be excluded from the task: Items 2 and 7. This was because the majority of participants commented that the terms tested in these items (radius and regular polygon) had never been taught to them. Two replacement items of a similar difficulty were written for the task as a result of this.

The internal reliability of the Year 5-6 mathematical vocabulary task was found to be α = .55; this increased to α = .56 following the removal of the selected items.

Table 3.10
Item Facility and Discrimination values; Year 5-6 Mathematical Vocabulary task

Item	Difficulty	Discrimination	Item	Difficulty	Discrimination
1	1.00*	.00*	11	1.00*	.00*
2	.33	.33	12	1.00*	.00*
3	.78	.00*	13	.67	.33
4	1.00*	.00*	14	.00*	.00*
5	.44	.33	15	.89*	.33
6	.44	1.00	16	.78	.33
7	.33	.00*	17	1.00*	.00*
8	1.00*	.00*	18	.89*	.33
9	1.00*	.00*	19	.78	.66
10	.56	1.00	20	.89*	.33

Note. * indicates item is recommended for removal

3.5.2.5 Group Statistics and Correlations

Table 3.11 presents descriptive statistics for the three piloted measures, split by both year group and language group. The results show that in both year groups, the FLE children outperformed the EAL children on the mathematical vocabulary measure. On the arithmetic computation tasks, the Year 3 EAL children outperformed the Year 3 FLE children, while the Year 5 FLE children marginally outperformed the Year 5 EAL children. Finally, the Year 3 FLE children scored higher on their WPS task than the Year 3 EAL children, while the opposite result was found in the Year 5 group.

Table 3.11
Descriptive statistics for the pilot tasks, split by language group

Measure	Year 3		Year 5	
	EAL	FLE	EAL	FLE
Arithmetic Computation	14.43	12.83	16.50	16.67
	(3.16)	(5.71)	(2.12)	(2.58)
Mathematical WPS	12.00	13.00	18.00	16.50
	(5.18)	(6.52)	(2.83)	(3.02)
Mathematical Vocabulary	63.00	72.73	65.00	76.43
(%)	(8.47)	(18.18)	(7.07)	(11.44)

Table 3.12 shows the correlations between arithmetic computation, WPS and mathematical vocabulary knowledge scores for the whole sample. Strong correlations were found between arithmetic computation and WPS ability, and between WPS ability and mathematical vocabulary knowledge. No significant correlation was found between arithmetic computation and mathematical vocabulary knowledge.

Table 3.12
Correlations between scores on the pilot tasks

	1.	2.
1. Arithmetic Computation		
2. WPS	.85***	
3. Mathematical Vocabulary (%)	.39	.57*

Note. * indicates $p < .05$, ** indicates $p < .01$, *** indicates $p < .001$

3.5.3 Discussion and Conclusions

Overall, all six of the researcher-designed tasks showed a good range of facility and discrimination values on their items, and the appropriate number of items were successfully identified for exclusion from the tasks, resulting in all tasks containing 15 items. As well as this, some items were modified based on their facility and discrimination values, and some other adjustments or replacements were made based on the researcher’s experience of administering the tasks. Overall, the Year 5-6 tasks showed more problematic facility and discrimination values and hence required more modification.

Four of the six tasks showed good or acceptable levels of internal reliability after modification, while the Year 5-6 arithmetic computation task and the Year 5-6 mathematical vocabulary task showed levels of $\alpha = .57$ and $\alpha = .56$ respectively. However, it should be considered that although these estimates accounted for item removal, they did not account for any other modifications that were made given that new data was not collected after modification. As reported in Section 3.4.2.2, both tasks showed good or acceptable levels of internal reliability when their final versions were used with the main study sample.

The process of piloting the bespoke tasks confirmed that approximately 20 items per task was too many for children of the sample age, particularly when administered alongside other tasks in the same session. Many of the children were overwhelmed by the number of questions or showed signs of fatigue while completing the tasks, with the result that some children did not complete the tasks fully. This was not unexpected, given that additional questions were written for each, allowing for exclusion of the weakest items, and it provided support for the planned reduction of each task to 15 items. Each of the parallel mathematical tasks took approximately 15 minutes for the participants to complete, although this varied substantially. Following the pilot study and the reduction of the task lengths, a decision was made to limit the time given to the participants for completion of these tasks to 10 minutes for the arithmetic computation tasks and 15 minutes for the WPS tasks. This was done to allow the timings of sessions to be planned more easily, and to ensure that participants were given an equal amount of time for the tasks, meaning none were advantaged over others. On average, the mathematical vocabulary tasks took between 5 and 10 minutes to complete. Following the pilot study, it was decided that the researcher would read the questions on the mathematical vocabulary tasks aloud to the participants during the main study, because some participants found it difficult or tiresome to read the questions themselves. This had the benefit that the task would be quicker to administer, and it also ensured that participants' ability to answer the questions was not influenced by their reading abilities.

The descriptive statistics calculated for the overall arithmetic computation, WPS and mathematical vocabulary scores were somewhat as expected based on the relevant literature discussed in Chapters 1 and 2. The literature suggests that EAL and FLE perform similarly on measures of arithmetic ability, but that FLE children typically outperform EAL children in WPS and mathematical vocabulary knowledge. The descriptive statistics for Year 5-6 arithmetic computation, Year 3-4 WPS and both mathematical vocabulary tasks followed these expected patterns. However, the Year 3-4 arithmetic computation results showed a small EAL advantage, perhaps due to the wide variation in the FLE scores on this task. In addition, the Year 5-6 WPS results showed the EAL children outperform the FLE children, which is surprising in light of the literature. However, given that the sample included only 2 Year 5 EAL children, this result should not be given too much weight. Indeed, given that no inferential statistics were calculated, these results should be interpreted as only a faint indication of potential performance in the main study.

The correlations between arithmetic computation, mathematical WPS and mathematical vocabulary knowledge presented above were as expected based on the literature, showing a very strong significant correlation between arithmetic computation and WPS ability (made stronger, ostensibly, by the parallel nature of the tasks), a strong significant correlation between mathematical vocabulary knowledge and mathematical WPS and finally no significant correlation between mathematical vocabulary knowledge and arithmetic computation. These results demonstrate that the tasks have good construct validity.

Both language questionnaires used were found to be effective and informative, and hence were not modified between the pilot study and the main study. However, during the pilot study, language background questionnaires were distributed along with the initial information sheets and consent forms, resulting in low recruitment numbers due possibly to the added paperwork. In light of this, a decision was made to distribute the parent language questionnaires to the parents of the EAL children in the main study only after they had given consent for their children to participate, in the hope that a higher recruitment rate might be achieved if the information sheets and consent forms were initially sent out alone.

A limitation that should be considered when interpreting the results of the pilot study is that some participants, usually from Year 5, observed that the same calculations were required for the arithmetic problems and the word problems and therefore answered some questions from memory despite completing the mathematical vocabulary task between the parallel tasks. This was not regarded as a concern for the main study, given that the procedure of the main study allowed for the tasks to be completed on two different days approximately a week apart, but in the pilot study this may have improved performance on the task each of these children completed second. Because counterbalancing was used, this issue did not affect the data for one task in particular; it is instead likely to have affected the data for both tasks equally.

Overall, the pilot study was successful in identifying items to be excluded from the bespoke tasks or modified, demonstrating the reliability and validity of the measures, identifying ways in which to make administration of the measures quicker and more consistent, and in giving an indication of how the performance of EAL and FLE children on the final tasks might compare.

3.6 Procedure of the Main Study

Participants completed the battery of tests at two separate time points during the main study: once during the academic year of 2019-20, and again a year later during the academic year of 2020-21. Data collection consisted of two individual sessions with each child at each time point, during which the standardised measures, the bespoke measures and the relevant questionnaires were administered. At T1, each session lasted approximately 40 minutes, while the T2 sessions lasted approximately 25 minutes due to the smaller test battery. Table 3.13 gives a summary of the schedule of testing, with the tasks for each session presented in the same order in which they were administered. The testing schedule was designed in such a way that more time-consuming tasks were carried out towards the start of sessions, and that tasks did not follow directly on from similar tasks. For example, no two mathematical tasks were completed in direct succession. Additionally, where relevant, language background or home learning questionnaires were completed before any other tasks in order to begin the sessions in a conversational manner. Data collection was carried out within each school during school hours and outside of break times. An effort was made by the researcher to ensure that all sessions were carried out undisturbed in a quiet room. However, in some schools, no separate room was available; in these cases, data collection was carried out at tables in corridors or shared spaces. When this was the case, background noise was largely minimal; only occasionally did data collection have to be paused briefly due to loud background noise or distraction. All children were offered a sticker at the end of each testing session and escorted back to their classrooms by the researcher.

Table 3.13
Overview of the testing schedule

	Measure
T1 Session 1	Child language background questionnaire (EAL participants only)
	YARC (Year 3: Beginning at passage 3A; Year 5: Beginning at passage 5A)
	Arithmetic Computation task (Year 3-4 or Year 5-6 version)
	WASI-II Vocabulary
	WASI-II Matrix Reasoning
	DTWRP
	Mathematical Vocabulary task (Year 3-4 or Year 5-6 version)
T1 Session 2	CTOPP-2 Phoneme Isolation
	CTOPP-2 Memory for Digits
	CTOPP-2 Rapid Digit Naming
	CTOPP-2 Rapid Letter Naming
	WPS task (Year 3-4 or Year 5-6 version)
	BPVS3
	TOBANS
	WMTB-C Backward Digit Recall
T2 Session 1	Home learning questionnaire
	YARC (Year 4: Beginning at passage 3A; Year 6: Beginning at passage 5A)
	Arithmetic Computation task (Year 3-4 or Year 5-6 version)
	WASI-II Vocabulary
	Mathematical Vocabulary task (Year 3-4 or Year 5-6 version)
T2 Session 2	WPS task (Year 3-4 or Year 5-6 version)
	BPVS3
	DTWRP
	TOBANS

3.7 Analysis Strategy

This section will discuss the methods used to analyse the data collected at both time points and the relevant methodological considerations.

3.7.1 General Approach

All data analysis was carried out using IBM SPSS Statistics for Windows, Version 28.0. During the design phase of the study, a data analysis plan was devised. While the statistical tests used remain the same as anticipated and will be described later in this section, the eventual overall approach to data analysis was adjusted due to ramifications of the COVID-19 pandemic and the associated school closures. Originally, it was intended to carry out each analysis separately for the Year 3 and the Year 5 children. However, due to the school closures, the final sample was smaller than expected; T1 data collection was ongoing when the UK school closures were announced on the 18th of March 2020 and was therefore indefinitely discontinued. This resulted in a loss of 19 recruited participants (13 EAL, 6 FLE; 11 Year 3, 8 Year 5) from one school in which data collection had not yet begun. Due to ongoing restrictions when schools reopened in the autumn term, it was not prudent to recruit further T1 participants. An additional loss of 30 participants occurred for the T2 sample only; 28 were lost due to further school closures in January 2021 and 2 due to attrition. Therefore, a decision was made to combine the year groups and control for age by including year group as a covariate during analysis in order to allow the use of the chosen statistical tests and to increase their statistical power. This was done initially for all analyses. In some cases, further exploratory analysis was carried out by year group to examine the effect of age; where this was done, a cautionary note is given due to the reduced sample sizes caused. In other cases, no further analyses beyond the presentation of descriptive statistics or correlations for each year group were carried out.

3.7.2 T1 Missing Data and Analyses

The T1 data was analysed using two main techniques: MANCOVA and multiple linear regression. MANCOVA analyses, controlling for year group, were carried out in order to compare the performance of the EAL and FLE groups on all measures, after composite variables had been created (this process is detailed in the relevant sections). In addition, some exploratory MANOVAs were run to assess the group differences separately for each year group. Multiple regression analyses, controlling for year group, were used in order to determine the concurrent predictors of reading comprehension, arithmetic computation and mathematical WPS in the EAL and FLE groups separately, again making use of composite variables. In addition, correlation analyses, or partial correlation analyses controlling for year group, were performed in several situations, either to inform the creation of composites, assess the relationships between variables prior to regression analysis or to provide information on the relationships between variables where regression analysis was not feasible due to reduced sample size. The results of all T1 analyses are presented in Chapters 4 and 5.

When the sudden school closures caused by the COVID-19 pandemic occurred in March 2020, some T1 participants had completed their first session of T1 data collection but not their second. This meant that 16 T1 participants only completed half of the battery of measures and thus had missing data for the remaining measures. As can be seen in Table 3.14, this resulted in seven variables missing 22% of data. In addition, an unrelated 1% of data for the mathematical vocabulary variable was missing due to a data collection session unexpectedly having to end early. Overall, 9.8% of data was missing.

Table 3.14
Overview of T1 missing data

Variable	Frequency	%
Reading Accuracy	0	0.00
Reading Rate	0	0.00
Reading Comprehension	0	0.00
Arithmetic Computation	0	0.00
Expressive Vocabulary	0	0.00
Non-verbal Ability	0	0.00
Word Reading	0	0.00
Mathematical Vocabulary	1	1.39
Phonological Awareness	16	22.22
Phonological Memory	16	22.22
RAN (time in seconds)	16	22.22
Mathematical WPS	16	22.22
Receptive Vocabulary	16	22.22
Arithmetic Fluency	16	22.22
Verbal Working Memory	16	22.22

To deal with the missing data, a decision was made to use multiple imputation (Rubin, 1987) to replace the missing values. Multiple imputation is a procedure whereby each missing value is substituted with a set of plausible values; in other words, *m* simulated datasets are generated. The substituted values are predicted using each participant's existing data and the relationships between the variables in those participants with no missing data, and thus take into account both the complete variables and those with missing data. After the substitute values have been generated, further analysis can be carried out on each simulated dataset separately, after which the results of these *m* analyses are pooled to give an overall result. Multiple imputation holds three main advantages over other methods of dealing with missing data. Firstly, multiple imputation makes use of all available data, preserving sample size and thus the statistical power of the analyses to be carried out. This is in contrast to listwise deletion, a commonly used method which discards all cases with missing data. Secondly, multiple imputation results in unbiased estimates of the missing data which reflect the uncertainty associated with predicting missing data, due to the creation of multiple simulated datasets and the pooling of analysis results; in contrast, methods such as single imputation or mean imputation treat the imputed data as “true” data and can thus lead to bias. Thirdly, multiple imputation is more lenient than other methods regarding the required pattern of missingness; multiple imputation can be used when data is missing at random or missing completely at random (MCAR), while listwise deletion, for example, should only be used when the data is MCAR. In addition, multiple imputation and further analysis of multiply imputed data are both easily implemented in standard statistical software such as SPSS and the subsequent results can be easily interpreted.

In order to determine whether the pattern of missingness was appropriate for multiple imputation, Little’s MCAR test was carried out on the data. The results of this showed the missing data to be MCAR, $\chi^2(15) = 13.55$, $p = .560$, thus allowing the use of multiple imputation. The multiple imputation itself was performed in SPSS ($m = 5$), using the linear regression method of prediction, and using all T1 variables as predictors. Limits for each variable with missing data were set based on the minimum and maximum values achievable in each measure. Five imputations were chosen due to a recommendation by Rubin (1987) that three to five imputations are sufficient with a moderate amount of missing data.

Analyses using the T1 data were carried out for all five imputations, and the results of these were pooled when necessary (i.e., for all analyses involving at least one variable with imputed data). Where possible, results were pooled using “Rubin’s rules” (Rubin, 1987). According to these rules, some statistics can be simply averaged across imputations while others require more complex pooling methods. Rubin’s rules do not cover all statistical tests, and thus for some methods of analysis, other pooling methods which were devised later in time are used. In the following chapters, the pooling method for each type of statistic is described at the first instance of that statistic. In some cases, the pooled statistics were given by SPSS. The pooling of other statistics is not currently supported by SPSS and therefore in these cases the pooling was done manually by the researcher. The use of Rubin’s rules often results in very large denominator degrees of freedom which are larger than the complete degrees of freedom value and are inappropriate for small samples; because of this, Barnard and Rubin (1999) proposed a formula which can be used to calculate a more appropriate value. As further recommended by Enders (2010) for studies employing multiple imputation with small samples, this method was implemented following the pooling of all relevant analyses.

3.7.3 T2 Analyses

The T2 data was analysed using the same primary methods of analysis as at T1: MANCOVA or ANCOVA and multiple linear regression. ANCOVA analyses, controlling for year group, were carried out in order to compare the EAL and FLE growth over time for all linguistic measures which were administered at both T1 and T2, due to the large number of measures and the lack of significant correlations between them. A MANCOVA was conducted to compare the EAL and FLE growth over time on the mathematical measures. In addition, multiple regression analyses were performed in order to examine the longitudinal predictors of reading comprehension, arithmetic computation and mathematical WPS in EAL and FLE children. Again, a number of correlation analyses, or partial correlation analyses controlling for year group, were performed to inform the creation of composite variables or to assess the relationships between variables prior to or following regression analysis. The results of these analyses are presented in Chapter 6. It should be noted that for the participants who were assessed at both T1 and T2, the data was complete in all cases and thus neither multiple imputation nor the subsequent pooling of results was necessary.

4 Reading Comprehension and its Predictors: Cross-Sectional Analysis

4.1 Introduction

This chapter focuses on the linguistic and cognitive skills of EAL and FLE children in Year 3 and Year 5, with overarching aims to compare the performance of the two groups on a range of linguistic and cognitive measures, and to investigate the concurrent predictors of reading comprehension in both groups. Cross-sectional differences between the language groups on measures of reading comprehension, language comprehension skills, decoding skills and cognitive ability, specifically non-verbal ability, are examined using MANCOVA analyses. Following this, regression analyses are carried out in order to determine and compare which underlying language comprehension, decoding and cognitive skills concurrently predict reading comprehension ability in both language groups. For the EAL children, the contribution of English language use outside of school to reading comprehension and vocabulary knowledge is also investigated. Longitudinal analysis is not carried out in this chapter; the Year 3 and Year 5 groups are two distinct groups of participants and thus the focus is on cross-sectional differences between these groups and the predictors of reading comprehension for the two groups separately.

There is evidence from government data that EAL children in England perform less well in literacy than FLE children (e.g., Strand et al., 2015), with the achievement gap narrowing with age. As well as age, the literacy performance of EAL children in England has been found to be highly dependent on their levels of PiE (Demie 2018a, 2018b; Hessel & Strand, 2021; Strand & Hessel, 2018; Strand & Lindorff, 2020, 2021). A growing field of research across the world has aimed to determine how EAL and other language-minority children perform on different linguistic measures in comparison to monolingual children, and to identify the linguistic and cognitive predictors of reading comprehension ability in these children.

As discussed in detail in Chapter 1, the language and literacy skills of EAL children have been well-researched in the literature, although only a small fraction of relevant studies were carried out in the UK. The existing empirical research carried out in the UK suggests that children learning EAL demonstrate significantly lower levels of reading comprehension than FLE children (e.g., Babayiğit, 2015; Beech & Keys, 1997; Burgoyne et al., 2009, 2011; Hutchinson et al., 2003; Rosowsky, 2001; Trakulphadetkrai et al., 2017), and this is reflected in international research, including a meta-analysis by Melby-Lervåg and Lervåg (2014) which demonstrated a moderate difference in reading comprehension scores between language-minority and monolingual children. Both UK-based and international research into the components of reading comprehension in EAL children has typically shown there to be no or minimal difference in decoding or cognitive abilities between EAL and FLE children (e.g., Babayiğit, 2014, 2015; Farnia & Geva, 2013; Geva & Farnia, 2012; Hutchinson et al., 2003; Lesaux et al., 2007; Melby-Lervåg & Lervåg, 2014), but has identified an EAL disadvantage in comprehension skills such as vocabulary, grammar and listening comprehension (e.g., Burgoyne et al., 2011; Farnia & Geva, 2011; Hessel & Murphy, 2018;

Hutchinson et al., 2003; Mahon & Crutchley, 2006; Melby-Lervåg & Lervåg, 2014). This suggests that the achievement gap in reading comprehension ability between EAL and FLE children in England can be attributed to a deficit in English language comprehension skills and not to English decoding skills.

As also discussed in Chapter 1, much of the existing literature investigating the predictors of reading comprehension has been guided by the SVR (Gough & Tunmer, 1986), and provides evidence that the main predictors of reading comprehension are decoding skills, such as reading accuracy, and comprehension skills, such as vocabulary knowledge (e.g., Dreyer & Katz, 1992; Kendeou, Savage & van den Broek, 2009; Muter et al., 2004; Nation & Snowling, 2004; Storch & Whitehurst, 2002). This has also been shown to be true for EAL and other language-minority children, both in the UK and elsewhere (e.g., Babayiğit, 2014, 2015; Bonifacci & Tobia, 2017; Geva & Farnia, 2012; Gottardo & Mueller, 2009; Lervåg & Aukrust, 2010; Verhoeven & van Leeuwe, 2012). There is evidence to suggest that vocabulary knowledge tends to be a stronger predictor of reading comprehension ability for language-minority children than for monolingual children (e.g., Babayiğit, 2014; Droop & Verhoeven, 2003; Hutchinson et al., 2003; Verhoeven, 2000), although the literature on this subject is mixed; evidence also exists which suggests that the strength of the predictors of reading comprehension in the two language groups are comparable (e.g., Babayiğit, 2015; Burgoyne et al., 2011; Lesaux et al., 2006, 2007; van Gelderen et al., 2003).

While evidence suggests that decoding and language comprehension skills are important predictors of reading comprehension ability in both EAL and FLE children, the influence that each component has on reading comprehension has been found to differ with age. In particular, some research has suggested that as children get older, their decoding skills reach or draw near to ceiling level and hence the contribution of decoding ability to reading comprehension ability diminishes, while comprehension skills remain a strong predictor of reading comprehension throughout development (e.g., Catts, Hogan & Adlof, 2005; García & Cain, 2014; Ouellette & Beers, 2010; Tilstra et al., 2009).

For EAL and other language-minority children in particular, another factor which has been found to influence their L2 comprehension skills is the level of L2 input they receive outside of school. Research from the USA and Canada has found that higher levels of L2 input result in higher vocabulary knowledge (Hoff et al., 2012; Lewis, Sandilos, Hammer, Sawyer & Méndez, 2016; Mancilla-Martinez & Lesaux, 2011; Quiroz, Snow & Zhao, 2010; Thordardottir, 2011). Similarly, a study carried out in Wales by Gathercole and Thomas (2009) found L2 Welsh vocabulary knowledge to increase with exposure to Welsh both inside and outside of school. Given the lack of research into the influence of English exposure outside of school on the language comprehension skills of EAL children in England, the current study seeks to assess this.

Taking the discussed research into account, the current chapter aims to replicate past research carried out in the UK which compares the performance of EAL and FLE children on various linguistic and cognitive measures, and investigates the concurrent predictors of reading comprehension for the two language groups. In addition, the current chapter will pay particular attention to the strength of the predictors of reading comprehension in each language group, given the mixed results on the subject found in the literature, as well as any differences in the predictors of reading comprehension for Year 3 and Year 5 children and the possible role of the proportion of English that EAL children use outside of school.

4.1.1 Research Questions and Hypotheses

This chapter addresses the first three research questions laid out in Section 2.5. These are:

1. How do the linguistic and cognitive skills of EAL children compare to those of FLE children in Year 3 and Year 5?
2. Which linguistic and cognitive skills concurrently predict reading comprehension in EAL and FLE children in Year 3 and Year 5?
3. To what extent does English language use outside of school concurrently predict reading comprehension in EAL children in Year 3 and Year 5?

Based on the discussed literature, it is hypothesised that the FLE children will outperform the EAL children on measures of reading comprehension and vocabulary knowledge, and that there will be no significant difference between the EAL and FLE children in terms of decoding ability and cognitive skills. In addition, it is expected that the group differences in reading comprehension and vocabulary knowledge scores will be smaller for the Year 5 children than the Year 3 children, in line with the narrowing of the achievement gap commonly seen in England. Regarding research question 2, it is predicted that both decoding skills and vocabulary knowledge will significantly predict reading comprehension concurrently in both FLE and EAL children, but that vocabulary knowledge will be a stronger predictor of reading comprehension for the EAL children. In addition, it is predicted that the contribution of decoding skills to reading comprehension will be smaller for the Year 5 children than for the Year 3 children. Finally, regarding research question 3, it is hypothesised that English use outside of school will be positively associated with vocabulary knowledge and thus also with reading comprehension ability in the EAL participants.

4.2 Method

4.2.1 Design and Participants

This chapter analyses a portion of the data collected at T1 of the current study, the overall design of which is laid out in Section 3.2.1. At T1, the sample consisted of 72 participants; of these, 33 were in Year 3 and 39 were in Year 5. The participants were recruited from the five primary schools described in Section 3.3.1. The Year 3 group consisted of 15 EAL children and 18 FLE children, with a mean (*SD*) age of 92.82 (4.78) months and had an approximately equal gender split of 17 males and 16 females. The Year 5 group consisted of 13 EAL and 26 FLE children, with a mean

(*SD*) age of 118.00 (4.11) months, but had a less equal gender split of 13 males and 26 females. However, as shown in Section 3.3.2, there were no significant differences in gender distribution between the EAL and FLE children in either age group. The L1s of the EAL children are also reported in Section 3.3.2.

For the initial analyses in this chapter, the Year 3 and Year 5 groups have been combined in order to increase statistical power and to allow for more complex analyses to be used, with age as a covariate. This decision was made due to the reduction in sample size caused by the school closures during the COVID-19 pandemic. The combined sample consisted of 28 EAL children and 44 FLE children and had a mean (*SD*) age of 106.46 (13.38) months. An independent samples *t*-test revealed no significant difference in age between the EAL ($M = 103.71$, $SD = 12.97$) and FLE children ($M = 108.20$, $SD = 13.49$) within the combined sample, $t(70) = 1.40$, $p = .167$. The combined sample had an approximately equal gender split, consisting of 42 females and 30 males, and the majority of the sample were not eligible for FSM, with only 16 out of the 72 participants (22%) being eligible. Chi square tests revealed no significant differences in gender distribution ($\chi^2(1) = 0.03$, $p = .870$) or FSM eligibility distribution ($\chi^2(1) = 0.02$, $p = .897$) between the two language groups within the combined sample.

4.2.2 Measures

The measures used to collect the data analysed in this chapter were the T1 linguistic and cognitive measures listed and described in detail in Section 3.4; a list is presented here in Table 4.1. In addition to the measures presented in Table 4.1, the language background questionnaires were distributed to the parents of all the EAL participants and the child version was also administered to all EAL participants.

Table 4.1
T1 test battery; linguistic and cognitive measures

Skill	Measure
Passage Reading	
Reading Comprehension	YARC
Reading Accuracy	YARC
Reading Rate	YARC
Decoding Skills	
Word Reading	DTWRP
Phonological Awareness	Phoneme Isolation; CTOPP-2
Speed of Lexical Access	Rapid Digit Naming & Rapid Letter Naming; CTOPP-2
Phonological Memory	Memory for Digits; CTOPP-2
Vocabulary	
Receptive Vocabulary	BPVS3
Expressive Vocabulary	Vocabulary; WASI-II
Mathematical Vocabulary	Bespoke task
Cognitive Skills	
Verbal Working Memory	Backward Digit Recall; WMTB-C
Non-verbal Ability	Matrix Reasoning; WASI-II

4.2.3 Procedure

The procedure for the T1 sessions followed the procedure and testing schedule detailed in Section 3.6. The measures were administered to the participants across two sessions, which were approximately one week apart. Each session lasted approximately 40 minutes, and was carried out with each child individually in a quiet place in their school during school hours.

4.3 Results

4.3.1 Descriptive Statistics: Linguistic and Cognitive Skills

Descriptive statistics were calculated for the whole sample in order to check the distribution of the scores on each language or cognitive measure; these can be found in Table 4.2. Pooled means were given by SPSS, while pooled *SD*, skewness and kurtosis values were calculated manually by taking the mean of the corresponding statistics across the five imputations.

Variables with high levels of skewness (i.e., above 1 or below -1) or kurtosis values above 2 or below -2 (George & Mallery, 2010) were tested for normality using the Shapiro-Wilk test. The

RAN variable was found to have a non-normal distribution by the Shapiro-Wilk test, $p < .001$ for all five imputations. Because of this, a reciprocal transformation was applied to the RAN variable. This gave the variable a normal distribution, reducing its skewness and kurtosis values to acceptable levels (-0.12 and -0.46 respectively), and rendering the Shapiro-Wilk test non-significant, $p > .05$ across all five imputations.

Table 4.2
Descriptive statistics for the linguistic and cognitive measures; whole sample

Measure	Mean	*SD*	Skewness	Kurtosis
Reading Accuracy	52.01	10.01	-0.28	-0.76
Reading Rate	65.63	16.16	-0.94	0.50
Reading Comprehension	57.00	10.20	-0.18	-0.44
Word Reading	65.92	15.67	-0.78	-0.28
Expressive Vocabulary	25.89	6.00	-0.69	1.88
Receptive Vocabulary	110.43	19.54	-0.20	-0.57
Mathematical Vocabulary	17.19	8.06	-0.08	-1.47
Phonological Awareness	21.75	5.03	-0.71	0.24
Phonological Memory	16.18	2.67	0.58	0.40
RAN (time in seconds)	40.35	8.26	1.26	2.54
Verbal Working Memory	11.45	4.08	0.69	0.16
Non-verbal Ability	12.97	4.40	-0.14	-0.50

Table 4.3 shows the mean raw scores for the EAL children and FLE children, both for the whole sample combined and for the year groups separately. The means for the whole sample show that the FLE children outperformed the EAL children to some extent on reading accuracy, reading rate, reading comprehension, receptive vocabulary, expressive vocabulary, mathematical vocabulary, phonological awareness and non-verbal ability. Conversely, the EAL group outperformed the FLE group to some extent on word reading, phonological memory, RAN and verbal working memory. The means for the year groups separately predominantly reflect the pattern of the whole sample means for both year groups, with some exceptions; interestingly, for reading accuracy and reading rate, the Year 5 means reflect the whole sample means while the Year 3 means instead show an EAL advantage. In addition, while the whole sample means for word reading are almost identical, the Year 3 means show a clear EAL advantage while the Year 5 means show a clear FLE advantage. These group differences will be tested inferentially later in this section.

Table 4.3
Mean (SD) raw scores split by language group; whole sample, Year 3 and Year 5

Measure	Whole sample		Year 3		Year 5	
	EAL	FLE	EAL	FLE	EAL	FLE
Reading Accuracy	50.86	52.75	47.33	44.89	54.92	58.19
	(10.02)	(10.04)	(7.24)	(7.90)	(11.47)	(7.47)
Reading Rate	64.68	66.23	57.33	54.44	73.15	74.38
	(15.07)	(16.95)	(13.12)	(18.48)	(12.85)	(9.63)
Reading Comprehension	53.75	59.07	50.07	52.83	58.00	63.38
	(9.36)	(10.27)	(6.12)	(8.83)	(10.80)	(9.01)
Word Reading	65.93	65.91	62.40	54.39	70.00	73.88
	(15.07)	(16.21)	(11.88)	(15.58)	(17.70)	(11.19)
Expressive Vocabulary	23.25	27.57	19.60	24.33	27.46	29.81
	(6.79)	(4.81)	(6.17)	(3.99)	(4.82)	(4.02)
Receptive Vocabulary	101.30	116.24	89.75	106.40	114.62	123.06
	(20.42)	(16.71)	(13.73)	(12.74)	(18.92)	(15.84)
Mathematical Vocabulary	15.11	18.51	8.47	9.63	22.77	24.65
	(7.94)	(7.95)	(3.50)	(1.83)	(2.95)	(3.21)
Phonological Awareness	21.15	22.13	21.14	21.37	21.15	22.65
	(4.99)	(5.07)	(4.04)	(4.67)	(6.08)	(5.33)
Phonological Memory	16.92	15.71	16.05	15.30	17.92	16.00
	(2.96)	(2.30)	(2.46)	(2.16)	(3.25)	(2.56)
RAN (time in seconds)	38.88	41.28	42.44	44.80	34.77	38.84
	(7.19)	(8.81)	(6.79)	(10.44)	(5.33)	(6.61)
Verbal Working Memory	12.11	11.03	11.54	9.87	12.77	11.83
	(4.05)	(4.09)	(3.20)	(3.89)	(4.90)	(4.08)
Non-verbal Ability	11.93	13.64	10.13	11.28	14.00	15.27
	(4.21)	(4.44)	(3.48)	(4.13)	(4.12)	(3.94)

In order to give an indication of the group differences between the EAL and FLE children before multiple imputation was carried out, the equivalent statistics using pairwise deletion on the original data only are presented in Appendix 14. Given that the two sets of descriptive statistics do not differ substantially, it does not seem likely that the use of multiple imputation will have meaningfully altered the results of the group comparisons beyond increasing their statistical power.

4.3.2 Correlations between the Variables and the Creation of Composite Variables

Due to the large test battery, it was anticipated that many of the measures would be intercorrelated. The absence of multicollinearity is an important assumption of running a MANCOVA and thus a decision was made to create composite variables, each combining several associated measures, to be used in the subsequent analyses. The creation of composite variables, as well as decreasing the risk of multicollinearity, reduced the number of outcome variables to be entered into the MANCOVA which, in light of the relatively small sample size, helped to increase the power of the analysis.

Table 4.4 shows the partial correlations between the linguistic and cognitive measures for the whole sample, controlling for year group. Pooled partial correlation coefficients were calculated by SPSS, and the corresponding pooled *p*-values were calculated using Fisher's Z transformation followed by Rubin's rules, as described by Heymans and Eekhout (2019). As expected, many of the variables were intercorrelated. Reading accuracy, reading rate and word reading were very strongly intercorrelated, as were the three vocabulary knowledge measures. Reading comprehension was strongly correlated with the vocabulary knowledge measures as well as with reading accuracy, reading rate and word reading. Phonological memory, RAN time and verbal working memory were all significantly correlated with reading rate, reading accuracy and word reading, as well as with each other. Surprisingly, phonological awareness was not significantly correlated with any other variable, aside from a moderate correlation with non-verbal ability, despite a strong theoretical link with both decoding and phonological skills; this suggests that the measure used (i.e., CTOPP-2 Phoneme Isolation) did not accurately assess phonological awareness. Finally, in addition to phonological awareness, non-verbal ability was moderately correlated with reading accuracy, word reading, all three vocabulary knowledge measures and reading comprehension.

Correlations between the variables using pairwise deletion on the original data only are presented in Appendix 15; given the similarity between the two sets of results, it seems that the use of multiple imputation did not meaningfully alter the relationships between the linguistic and cognitive variables found in the original data.

Table 4.4
Partial correlations between all T1 linguistic and cognitive variables, controlling for year group

	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.
1. Reading Accuracy											
2. Reading Rate	.80***										
3. Reading Comprehension	.57***	.60***									
4. Word Reading	.87***	.86***	.61***								
5. Expressive Vocabulary	.41***	.45***	.62***	.39***							
6. Receptive Vocabulary	.32**	.36**	.56***	.28*	.71***						
7. Mathematical Vocabulary	.42***	.46***	.58***	.47***	.63***	.57***					
8. Phonological Awareness	.06	-.07	.02	.03	.20	.14	.16				
9. Phonological Memory	.31**	.37**	.09	.37**	.08	.17	.15	.19			
10. RAN (time in seconds)	-.30**	-.48***	-.22	-.46***	-.03	-.12	-.18	-.11	-.45***		
11. Verbal Working Memory	.30**	.27*	.10	.30**	-.04	.07	.07	.09	.47***	-.41***	
12. Non-verbal Ability	.28*	.13	.35**	.28*	.36**	.26*	.34**	.31**	-.01	.04	.03

Note. * indicates $p < .05$, ** indicates $p < .01$, *** indicates $p < .001$

Given that many variables were intercorrelated, an exploratory factor analysis was carried out in order to further ascertain which variables should be aggregated into each composite. Reading comprehension was excluded from this analysis due to being the primary outcome measure of interest in this chapter and was thus entered into further analyses independently or as the outcome measure. A Principal Components Analysis (PCA) using the Varimax rotation method was conducted. Generalised Procrustes Analysis, as described in detail by van Ginkel and Kroonenberg (2014), was used to carry out the PCA with the multiply imputed data and to pool the results, using SPSS syntax presented by van Wingerde and van Ginkel (2021). Across all five imputations, Bartlett's test of sphericity was significant ($p < .001$), the Kaiser-Meyer-Olkin Measure of Sampling Adequacy (KMO) showed a high strength of relationships between the variables (KMO ranged from .82 to .85), and all communalities exceeded .50, meaning the data was suitable for PCA and analysis could proceed. For all imputations, three components with eigenvalues greater than 1 were extracted and the amount of variance explained by the components ranged from 73.1% to 74.5% across the five imputations. Table 4.5 shows the pooled rotated component matrix for the three extracted components.

Table 4.5
Pooled Factor Loadings

Variable	Factor 1	Factor 2	Factor 3
Expressive Vocabulary	0.89		
Mathematical Vocabulary	0.84		
Receptive Vocabulary	0.80		
Reading Accuracy	0.78	0.44	
Reading Rate	0.77	0.48	
Word Reading	0.72	0.51	
Non-verbal Ability	0.66		0.41
RAN Time		0.73	
Phonological Awareness			0.89
Phonological Memory		0.80	
Verbal Working Memory		0.79	

Note. Loadings < .30 have been suppressed

The results of the PCA alone did not conclusively reveal a number of distinct components to inform the creation of composites for use in the later analyses, given that four variables (reading accuracy, reading rate, word reading and non-verbal ability) cross-loaded onto two components. The results, however, do begin to suggest some meaningful groupings of the measures. A decision was made to assign the measures to composites based partly on the evidence from the PCA and partly theoretically based on the SVR (Gough & Tunmer, 1986), alongside evidence from the correlation matrix presented in Table 4.4. The SVR states that reading comprehension is comprised of two distinct components: decoding and language comprehension.

Based on the SVR, the first composite variable created was "Decoding", consisting of reading accuracy, reading rate, word reading, verbal working memory, phonological memory and RAN time. These six variables loaded onto Factor 2 of the PCA, are strongly intercorrelated and theoretically fall into the decoding component of the SVR, which includes phonological skills. The second composite variable created was "Vocabulary", consisting of receptive vocabulary, expressive vocabulary and mathematical vocabulary. These three variables loaded very strongly onto Factor 1 of the PCA, are strongly intercorrelated and theoretically fall into the language comprehension component of the SVR. In both cases, composites were created through the conversion of the relevant scores to *z*-scores and then the calculation of the mean *z*-score of the corresponding measures; this was done for each imputed dataset separately, thus maintaining five distinct datasets to be analysed. The RAN time *z*-scores were multiplied by -1 prior to calculation of the decoding composite scores in order to ensure that a higher score represented a better performance for all variables.

Two variables were not included in either of the composites; these were non-verbal ability and phoneme isolation. Given that non-verbal ability correlated moderately with a range of other variables and is theoretically distinct from reading ability, it was decided that the non-verbal ability variable would be included in further analyses as an independent measure. Although theoretically belonging to the decoding component of the SVR, phonological awareness neither correlated significantly with any other variable nor loaded onto either Factor 1 or 2 and was therefore not included in the decoding composite nor indeed in any further analysis.

Table 4.6 presents descriptive statistics for the two composite variables across the whole sample. Both composites were considered to be normally distributed based on their skewness and kurtosis values, using the guidelines specified in Section 4.3.1, and were thus suitable to be included in the subsequent analyses without modification.

Table 4.6
Descriptive statistics for the T1 linguistic composite variables; whole sample

Measure	Mean	Standard Deviation	Skewness	Kurtosis
Decoding Composite	0.00	0.77	-0.54	0.04
Vocabulary Composite	0.00	0.91	-0.25	-0.30

4.3.3 EAL and FLE Differences on the Linguistic and Cognitive Measures

In order to compare the performance of EAL and FLE children on the linguistic and cognitive measures and thus answer research question 1, a one-way MANCOVA was run. The outcome variables entered into the model were reading comprehension, the decoding composite, the vocabulary composite and non-verbal ability, and year group was entered as a covariate because the sample consisted of both Year 3 and Year 5 children. Because of the relatively small sample sizes and the unequal group sizes (28 EAL children and 44 FLE children), Pillai's trace (*V*) was used in this analysis and in all such analyses throughout this thesis. Effect sizes (Cohen's *d*) are reported in order to represent the magnitude of the difference between the language groups on each outcome measure. Throughout this thesis, following the guidelines set out by Cohen (1988), effect sizes from 0.20 will be interpreted as representing small effects, values from 0.50 will be interpreted as medium effects and values above 0.80 will be interpreted as large effects. Where relevant, both Cohen's *d* and the corresponding 95% confidence intervals were pooled by averaging across the five imputations.

In order to pool the overall results of each relevant MANCOVA or MANOVA carried out within this thesis, given that this is not supported in SPSS, the method proposed by Licht (2010), and as supported for use in multivariate analysis by Finch (2016), was used to calculate pooled *p*-values and degrees of freedom. Following this, because this method consistently resulted in inflated degrees of freedom, the correction formula proposed by Barnard and Rubin (1999) was applied (as discussed in Section 3.7.2). Using these statistics, the pooled *F* values were derived from the *F*-distribution. In addition, Pillai's trace statistics were pooled by taking the average across the five imputations. The same method was also used to pool the individual results for each dependent variable within each multivariate analysis.

Before the MANCOVA was carried out, various assumptions of the analysis were checked. There was no evidence of multicollinearity between the outcome variables; all correlations fell below $r = .90$. The assumption of homogeneity of variances was met for all outcome variables using Levene's test, $p > .05$ for all variables across all imputations. Similarly, the assumption of homogeneity of covariance, tested using Box's *M* test, was met, $p > .05$ across all imputations. Finally, significant linear relationships were found between all included variables.

The results of the MANCOVA can be seen in Table 4.7. The MANCOVA revealed a significant effect of language group on the combined outcome measures, $V = .25$, $F(4, 61.44) = 5.62$, $p < .001$, as well as a significant effect of year group, $V = .61$, $F(4, 62.77) = 26.03$, $p < .001$. As expected, the FLE group scored significantly higher than the EAL group on the vocabulary composite, $F(1, 66.77) = 11.84$, $p = .001$, with a medium effect size. Also in line with expectations, the language groups did not differ significantly on the decoding composite or on non-verbal ability. Surprisingly, there was no significant difference in reading comprehension between the language groups, although the difference was approaching significance ($p = .058$).

Table 4.7
MANCOVA results for the T1 linguistic and cognitive variables; combined year groups

Variable	EAL Mean	FLE Mean	*F*	*p*	Effect Size [95% CIs]
Decoding Composite	0.07	-0.05	1.84	.179	-0.16
	(0.75)	(0.80)			[-0.63, 0.32]
Vocabulary Composite	-0.39	0.25	11.84	.001	0.74
	(0.97)	(0.78)			[0.25, 1.23]
Non-Verbal Ability	11.93	13.64	1.62	.208	0.39
	(4.21)	(4.44)			[-0.09, 0.87]
Reading Comprehension	53.75	59.07	3.71	.058	0.54
	(9.36)	(10.27)			[0.05, 1.02]

Note: Effect Size is Cohen's *d* with 95% Confidence Intervals [Lower Limit, Upper Limit].

The MANCOVA showed a significant effect of year group on all four outcome measures, suggesting that the Year 3 and Year 5 group differences might differ in some way. Because of this, exploratory MANOVAs were carried out for each year group separately; the results of these are presented in Table 4.8. In both cases, the data was found to meet the assumptions of MANOVA analysis, however these results should nevertheless be interpreted with caution due to the reduced sample sizes for these analyses.

The Year 3 MANOVA revealed a significant effect of language group on the combined outcome measures, $V = .38$, $F(4, 25.87) = 4.38$, $p = .008$. The FLE children significantly outperformed the EAL children on the vocabulary composite, $F(1, 28.86) = 10.62$, $p = .003$, with a large effect size. The language groups did not differ significantly on any other measure. The Year 5 MANOVA revealed there to be no significant effect of language group on the combined outcome measures, $V = .18$, $F(4, 27.55) = 1.93$, $p = .132$. Predominantly, these results reflect those of the combined MANCOVA, again showing no significant difference between the groups on the decoding composite, reading comprehension and non-verbal ability for either year group. Furthermore, these results reveal that the language groups only differ significantly on their vocabulary knowledge within the Year 3 group, with the difference being non-significant for the Year 5 group.

Table 4.8
MANOVA results for the T1 linguistic and cognitive variables; separate year groups

	Year 3					Year 5				
Variable	EAL Mean	FLE Mean	*F*	*p*	Effect Size [95% CIs]	EAL Mean	FLE Mean	*F*	*p*	Effect Size [95% CIs]
Decoding Composite	-0.26 (0.63)	-0.56 (0.76)	1.45	.238	-0.43 [-1.12, 0.27]	0.46 (0.69)	0.31 (0.61)	0.44	.513	-0.24 [-0.91, 0.43]
Vocabulary Composite	-1.06 (0.61)	-0.47 (0.43)	10.62	.003	1.15 [0.40, 1.88]	0.39 (0.68)	0.74 (0.55)	2.99	.093	0.59 [-0.09, 1.27]
Non-Verbal Ability	10.13 (3.48)	11.28 (4.13)	0.72	.402	0.30 [-0.39, 0.98]	14.00 (4.12)	15.27 (3.94)	0.87	.356	0.32 [-0.35, 0.99]
Reading Comprehension	50.07 (6.12)	52.83 (8.83)	1.05	.313	0.36 [-0.34, 1.05]	58.00 (10.80)	63.38 (9.01)	2.71	.108	0.56 [-0.12, 1.23]

Note: Effect Size is Cohen’s *d* with 95% Confidence Intervals [Lower Limit, Upper Limit].

Given that the Year 3 language groups were found to differ significantly on the vocabulary composite variable, a further MANOVA was performed in order to determine on which of the vocabulary measures the language groups differed. The data was deemed suitable for MANOVA analysis after the assumptions of the test were checked, although again these results should be interpreted with caution given the reduced sample size. The results of the MANOVA are presented in Table 4.9. The Year 3 MANOVA revealed a significant effect of language group on the combined vocabulary measures, $V = .32$, $F(3, 25.95) = 4.74$, $p = .009$. The FLE children significantly outperformed the EAL children in receptive vocabulary knowledge, $F(1, 26.93) = 11.89$, $p = .002$, and expressive vocabulary knowledge, $F(1, 31) = 7.07$, $p = .012$, but not in mathematical vocabulary knowledge. A greater difference was found between the groups for receptive vocabulary knowledge, although in both cases the effect size was large.

Table 4.9
MANOVA results for the T1 vocabulary measures; Year 3 group

Variable	EAL Mean	FLE Mean	*F*	*p*	Effect Size [95% CIs]
Receptive Vocabulary	89.75	106.40	11.89	.002	1.26
	(13.73)	(12.74)			[0.50, 2.01]
Expressive Vocabulary	19.60	24.33	7.07	.012	0.93
	(6.17)	(3.99)			[0.20, 1.65]
Mathematical Vocabulary	8.47	9.63	1.47	.235	0.43
	(3.50)	(1.83)			[-0.27, 1.12]

Note: Effect Size is Cohen's *d* with 95% Confidence Intervals [Lower Limit, Upper Limit].

4.3.3.1 Summary

To summarise, the analyses presented in this section showed the FLE children to significantly outperform the EAL children on a composite vocabulary knowledge measure. Further analyses revealed that this difference was significant in the Year 3 group only, and that, in particular, the Year 3 EAL group struggled with receptive and expressive vocabulary in comparison to their FLE peers, but not with mathematical vocabulary. Although, on average, the EAL children scored lower than the FLE group on reading comprehension, this difference was found to be non-significant. In addition, no significant difference was found between the groups on the decoding composite or on a measure of non-verbal ability.

4.3.4 The Concurrent Predictors of Reading Comprehension

In order to investigate the concurrent linguistic and cognitive predictors of reading comprehension in EAL and FLE children and thus answer research question 2, a series of multiple linear regression models were run. In order to maximise statistical power, a single initial regression analysis was run on the whole sample, entering year group and language group into the model as predictors in order to assess whether the predictors of reading comprehension differed for the year groups or for the language groups. The assumptions of multiple linear regression, including linearity of relationships, absence of multicollinearity and homoscedasticity were checked for all models, and no violations of the assumptions were evident. In addition to language group status and year group, the independent variables entered into the model were the decoding composite, the vocabulary composite and non-verbal ability. The individual contribution of working memory to reading comprehension was not examined, despite its established link with reading comprehension, due to the fact that the working memory variable was included in the decoding composite. The independent variables were entered into the models simultaneously, allowing the unique contribution of each to be assessed.

The results of all multiple regression analyses conducted within this thesis which utilised the T1 data were pooled across the five imputations in several ways. Firstly, the adjusted R^2 values for each model were pooled through taking the average across the imputations. The overall significance levels of each regression model were pooled through the use of Licht's (2010) method followed by application of Barnard and Rubin's (1999) degrees of freedom correction formula and the subsequent derivation of the corresponding *F*-value. Pooled *t*- and *p*-values for each predictor within each model were given in SPSS. Given that SPSS also supports the pooling of *B* values and their associated *SE* values for each predictor, pooled β and their associated *SE* values were obtained directly from SPSS after repeating each regression analysis using the standardised form of each variable. Finally, pooled semi-partial correlation values were also given in SPSS, allowing the pooled unique R^2 for each predictor to be calculating by squaring these values.

The results of the initial regression model are presented in Table 4.10. The model significantly accounted for 61% of the variance in reading comprehension, $F(5, 61.75) = 22.63$, $p < .001$. Both decoding ability and vocabulary knowledge significantly predicted reading comprehension, uniquely accounting for 5% and 12% of the variance in reading comprehension respectively, making vocabulary knowledge a stronger predictor of reading comprehension than decoding. Non-verbal ability did not significantly predict reading comprehension. In addition, neither year group nor language group were significant predictors, suggesting that, overall, the predictors of reading comprehension are comparable across the year groups and the language groups.

Table 4.10
Multiple regression model predicting reading comprehension; whole sample

Predictor	Adjusted R^2	β (*SE*)	*t*	*p*	Unique R^2
	.61				
Year Group		-.21 (.12)	-1.82	.069	.02
Language Group		-.06 (.09)	-0.67	.503	< .01
Decoding Composite		.30 (.10)	2.97	.003	.05
Vocabulary Composite		.65 (.14)	4.53	< .001	.12
Non-verbal Ability		.12 (.09)	1.37	.172	.01

Note. Unique R^2 is represented by squared semi-partial correlations

Despite the fact that language group did not have a significant effect on the predictors of reading comprehension, further regression analyses were performed for the language groups separately in order to enable comparison of the strength of the predictors in each language group. The variables entered into these models were the decoding composite, the vocabulary composite, non-verbal ability and year group. It should be noted that carrying out the regression analysis separately for each language group resulted in reduced sample sizes and thus the results of these analyses should be interpreted with caution. In light of this, the partial correlations between the variables of interest and reading comprehension, controlling for year group, are presented for each language group in Table 4.11.

Table 4.11
Partial correlations between the T1 variables of interest and reading comprehension, controlling for year group; EAL above diagonal, FLE below diagonal.

	1.	2.	3.	4.
1. Decoding Composite		.50**	.12	.44*
2. Vocabulary Composite	.43**		.18	.68***
3. Non-verbal Ability	.21	.45**		.31
4. Reading Comprehension	.57***	.65***	.34*	

Note. * indicates $p < .05$, ** indicates $p < .01$, *** indicates $p < .001$

The results of the multiple regression analyses are presented in Table 4.12. Results of the regression analysis for the EAL group found the model to significantly account for 53% of the variance in reading comprehension, $F(4, 21.22) = 8.62$, $p < .001$. The regression analysis for the FLE group found the model to significantly account for 61% of the variance in reading comprehension scores, $F(4, 36.16) = 16.60$, $p < .001$.

As can be seen in Table 4.12, the strongest and only significant predictor of reading comprehension for the EAL group was the vocabulary composite. For the FLE group, both the vocabulary composite and the decoding composite made a unique significant contribution to reading comprehension. Vocabulary knowledge accounted for more variance in reading comprehension for the EAL children than for the FLE children, uniquely explaining 20% of the variance in reading comprehension in the EAL group compared to 11% in the FLE group. Decoding ability uniquely explained a further 8% of the variance in reading comprehension for the FLE group. Non-verbal ability did not significantly predict reading comprehension for either of the language groups. This was also true for year group, suggesting that the predictors of reading comprehension are similar for Year 3 and Year 5 children within each language group.

Table 4.12

Multiple regression models predicting reading comprehension; separate language groups

Predictor	EAL					FLE				
	Adjusted R^2	β (*SE*)	*t*	*p*	Unique R^2	Adjusted R^2	β (*SE*)	*t*	*p*	Unique R^2
	.53					.61				
Year Group		-.31 (.19)	-1.62	.104	.05		-.20 (.15)	-1.32	.188	.02
Decoding Composite		.13 (.17)	0.80	.424	.01		.36 (.13)	2.82	.005	.08
Vocabulary Composite		.69 (.20)	3.39	< .001	.20		.73 (.21)	3.42	< .001	.11
Non-verbal Ability		.19 (.15)	1.28	.200	.03		.06 (.12)	0.49	.624	< .01

Note. Unique R^2 is represented by squared semi-partial correlations

Although year group had no significant effect on the predictors of reading comprehension in the initial model, further regression analyses were also performed for the Year 3 children and Year 5 children separately in order to investigate the strength of each predictor for each year group. The variables entered into these models were the decoding composite, the vocabulary composite, non-verbal ability and language group. Again, it should be remembered that carrying out the regression analysis separately for each year group resulted in reduced sample sizes, lowering the statistical power of these analyses. In light of this, correlations between the variables of interest and reading comprehension for each year group are presented in Table 4.13. Both the pooled correlation coefficients and the pooled *p*-values were calculated in SPSS.

Table 4.13
Correlations between the T1 variables of interest and reading comprehension; Year 3 above diagonal, Year 5 below diagonal.

	1.	2.	3.	4.
1. Decoding Composite		.22	.03	.50**
2. Vocabulary Composite	.46**		.17	.70***
3. Non-verbal Ability	.25	.51***		.16
4. Reading Comprehension	.45**	.65***	.48**	

Note. * indicates $p < .05$, ** indicates $p < .01$, *** indicates $p < .001$

The results of the multiple regression analyses by year group are presented in Table 4.14. The Year 3 model significantly accounted for 57% of the variance in reading comprehension, $F(4, 26.09) = 11.42$, $p < .001$. Year 5 model significantly accounted for 44% of the variance in reading comprehension scores, $F(4, 31.65) = 8.11$, $p < .001$.

As can be seen in Table 4.14, both decoding and vocabulary significantly predicted reading comprehension in the Year 3 group, uniquely accounting for 9% and 27% of the variance in reading comprehension respectively. In the Year 5 group, only vocabulary was a significant predictor, uniquely accounting for 4% of the variance in reading comprehension scores and demonstrating that decoding was not a significant predictor of reading comprehension in the Year 5 group. Non-verbal ability was not a significant predictor of reading comprehension in either year group. This was also the case for language group, suggesting that the predictors of reading comprehension do not differ between the language groups within each year group.

Table 4.14

Multiple regression models predicting reading comprehension; separate year groups

Predictor	Year 3					Year 5				
	Adjusted R^2	β (*SE*)	*t*	*p*	Unique R^2	Adjusted R^2	β (*SE*)	*t*	*p*	Unique R^2
	.57					.44				
Language Group		.07 (.11)	0.61	.545	< .01		-.15 (.13)	-1.13	.257	.02
Decoding Composite		.28 (.11)	2.63	.009	.09		.29 (.18)	1.61	.108	.04
Vocabulary Composite		.76 (.17)	4.48	< .001	.27		.57 (.24)	2.38	.017	.09
Non-verbal Ability		.05 (.10)	0.49	.623	< .01		.20 (.15)	1.36	.175	.03

Note. Unique R^2 is represented by squared semi-partial correlations

Given the reduced sample sizes already caused by analysing the predictors of reading comprehension separately for certain sub-groups, it was deemed unnecessary and unsuitable to perform additional multiple regression analyses split by both language group and year group. However, in order to give some representation of the magnitude of these relationships in each language group within each year group, correlation analyses were carried out; the results of these can be seen in Table 4.15. These results show that the correlates of reading comprehension are largely the same across each year group for each language group, but in both cases the strength of the relationship is slightly diminished in Year 5 relative to in Year 3.

Table 4.15
Correlations between the T1 variables of interest and reading comprehension; Year 3 above diagonal, Year 5 below diagonal.

	EAL				FLE			
	1.	2.	3.	4.	1.	2.	3.	4.
1. Decoding Composite		.52*	-.16	.45		.29	.19	.62**
2. Vocabulary Composite	.48		-.08	.79***	.55**		.30	.73***
3. Non-verbal Ability	.36	.41		.01	.22	.54**		.21
4. Reading Comprehension	.45	.64*	.49		.54**	.61***	.44*	

Note. * indicates $p < .05$, ** indicates $p < .01$, *** indicates $p < .001$

4.3.4.1 The Contribution of English Use Outside of School to Reading Comprehension in EAL Children

In order to assess whether English language use outside of school is a predictor of reading comprehension in the EAL children and thus answer research question 3, the data collected by the language background questionnaires at T1 was used to create variables representing English use outside of school. Two variables were created by converting the answers to certain questions into percentages. These pertained to how often each child spoke English in the home and how often each child used English when speaking with different family members and friends, and they were taken from Questions 7 and 12 in the child language questionnaire, due to the low response rate for the corresponding parent questionnaire. In addition, an average English use outside of school variable was created by taking the mean of the two scores for each EAL child. Table 4.16 shows the partial correlations, controlling for year group, between these variables and the T1 language outcomes for the EAL group. The only English use variable to correlate significantly with any language outcomes was English use with family and friends; this showed a significant moderate correlation with both vocabulary knowledge and reading comprehension.

Table 4.16
Partial correlations, controlling for year group, between English use outside of school and T1 language outcomes; EAL group

	Vocabulary Composite	Decoding Composite	Reading Comprehension
Average English use	.25	.30	.33
English use in the home	.10	.23	.19
English use with family and friends	.39*	.32	.42*

Note. * indicates $p < .05$, ** indicates $p < .01$, *** indicates $p < .001$

Due to this significant correlation, a further regression analysis was carried out in order to establish whether English use with family and friends was a significant predictor of reading comprehension for the EAL children. A hierarchical regression analysis was run, consisting of two models. Model 1 investigated the English use variable as a predictor of reading comprehension, controlling only for year group. The vocabulary composite, which was found to be the sole predictor of reading comprehension for the EAL group in the previous section, was added into Model 2 in order to assess whether English use predicted reading comprehension above and beyond the contribution of vocabulary knowledge.

The results of the hierarchical regression analysis are presented in Table 4.17. Model 1 was found to significantly predict reading comprehension, $F(2, 25) = 6.14$, $p = .007$, accounting for 28% of the variance in reading comprehension scores. Both year group and English use with family and friends significantly predicted reading comprehension scores. Model 2 also significantly predicted reading comprehension scores, $F(3, 22.22) = 11.13$, $p < .001$, and accounted for 53% of the variance in reading comprehension scores. Both year group and English use with family and friends were no longer significant predictors of reading comprehension after the inclusion of the vocabulary composite; this suggests that English use with family and friends indirectly predicts reading comprehension through vocabulary knowledge.

Table 4.17

Hierarchical regression models predicting reading comprehension; EAL group

Predictor	Adjusted R^2	β (*SE*)	*t*	*p*	Unique R^2
Model 1	.28				
Year Group		.46 (.15)	3.02	.003	.24
English use with family and friends		.35 (.15)	2.32	.020	.14
Model 2	.53				
Year Group		-.16 (.20)	-0.79	.428	.01
English use with family and friends		.15 (.13)	1.14	.254	.02
Vocabulary		.72 (.19)	3.80	< .001	.25

Again, no further regression analyses were carried out to investigate the year groups within the EAL group separately; however, correlation analyses between the variables of interest in these models were carried out for the Year 3 and Year 5 groups separately in order give a representation of the strength of these relationships in each year group. These are presented in Table 4.18. There are strong positive correlations between English use with family and friends and both reading comprehension and vocabulary knowledge in the Year 3 group; however, there are no significant correlations between English use with family and friends and language outcomes in the Year 5 group; this indicates that English use outside of school is more strongly related to reading outcomes for younger EAL children.

Table 4.18

Correlations between the English use variables and reading comprehension for the EAL group; Year 3 above diagonal, Year 5 below diagonal.

	1.	2.	3.
1. English use with family and friends		.61*	.54*
2. Vocabulary Composite	.16		.79***
3. Reading Comprehension	.37	.64*	

Note. * indicates $p < .05$, ** indicates $p < .01$, *** indicates $p < .001$

4.3.4.2 Summary

To summarise, both decoding ability and vocabulary knowledge were found to be strong concurrent predictors of reading comprehension for the combined sample. However, further analyses per group revealed that only language comprehension significantly predicted reading comprehension in the EAL group, while both predictors remained significant in the FLE group. Language comprehension uniquely accounted for more variance in reading comprehension for the EAL children than for the FLE children. Analysis of the year groups separately revealed decoding ability to predict reading comprehension in the Year 3 group but not the Year 5 group, suggesting a decline of the contribution of decoding ability to reading comprehension with age. In addition, English use with family and friends was found to indirectly predict reading comprehension through vocabulary knowledge for the EAL children. Correlations carried out for the year groups separately suggested that English use outside of school is only important to language outcomes for the Year 3 children; by Year 5, it seems that this relationship disappears.

4.4 Discussion

This chapter investigated the linguistic and cognitive skills of English EAL and FLE children in KS2, specifically comparing the performance of the two language groups on these measures as well as the concurrent predictors of reading comprehension in each group. It was hypothesised that the EAL children would score significantly lower than their FLE peers on the measures of reading comprehension and language comprehension, to a greater extent in Year 3 than in Year 5, while there would be no significant difference between the language groups on all decoding and cognitive measures. Regarding the concurrent predictors of reading comprehension, it was hypothesised that both decoding ability and language comprehension skills would significantly predict reading comprehension in both language groups, but that language comprehension would predict EAL reading comprehension more strongly. Furthermore, it was hypothesised that decoding skills would predict reading comprehension more strongly for the Year 3 children relative to the Year 5 children. In addition, English exposure outside of school was expected to be positively associated with language outcomes in the EAL group. The results presented in Section 4.3 reflect the hypotheses to some extent. This section will discuss each finding in turn, detailing each finding's relevance to the hypotheses as well as previous results from the literature and the educational implications of the results.

In line with the predictions, the EAL children were found to have significantly weaker language comprehension skills (represented by three measures of vocabulary knowledge) than the FLE children overall, with a large effect size, but to have comparable levels of decoding skills and non-verbal ability. These findings concur with those of the vast majority of both UK and international studies in the literature (e.g., Babayiğit, 2014; Hutchinson et al., 2003; Melby-Lervåg & Lervåg, 2014; Xu et al., 2021) in demonstrating that the linguistic weaknesses of EAL and language-minority children indeed lie in language comprehension and not in decoding. This is likely because they are able to transfer their decoding skills, but not their language comprehension skills, across languages (e.g., Melby-Lervåg & Lervåg, 2011). Contrary to the hypotheses, however, no significant overall difference in reading comprehension ability was found between the language groups. This result contradicts the vast majority of the literature comparing the reading comprehension abilities of EAL and FLE children (e.g., Burgoyne et al., 2009; Hutchinson et al., 2003; Melby-Lervåg & Lervåg, 2014) which has typically found FLE children to significantly outperform EAL children in reading comprehension, though it is in accordance with some studies which found no significant difference between the groups (e.g., Bowyer-Crane et al., 2017; Lesaux et al., 2007). Given that in the current study, the FLE children did show higher levels of reading comprehension than the EAL children ($d = 0.54$) and that the EAL children showed a significant weakness in language comprehension, a key component of reading comprehension, it seems that a lack of statistical power is most likely to explain this nonsignificant result; there is no evidence to suggest that the language groups scored equally or that the EAL group outperformed the FLE group and indeed the significance level for this group comparison was approaching significance ($p = .058$). As discussed previously, the sample size for the current study was lower than expected due to the school closures caused by the COVID-19 pandemic; it is highly probable that the gap in reading comprehension ability would have reached significance with a slightly larger sample. It is also possible that the measure of reading comprehension used was a contributing factor to the non-significant result; reading comprehension scores on the YARC are somewhat dependent on each participant's word reading ability due to forced discontinuation of administration on making a certain number of reading errors. It is possible that the use of another measure which is independent of other factors might have given a more valid assessment of reading comprehension. Furthermore, use of multiple tests of reading comprehension might have resulted in more accurate measurement; there is evidence that different tests of reading comprehension assess differing proportions of literal and inferential comprehension (Bowyer-Crane & Snowling, 2005) and thus a combination of measures might give a more rounded assessment of reading comprehension. While this was not possible in the current study due to the already large battery of tests, future research should consider employing multiple measures of reading comprehension.

Exploratory analyses were carried out for each year group separately following the initial MANCOVA, given the significant effect of age on the combined sample. These results showed a greater mean vocabulary knowledge deficit for the EAL children in Year 3 than in Year 5, in line with the hypothesis that the gap between the language groups would narrow over time. However, the group difference was statistically significant for the Year 3 group only, suggesting that the linguistic abilities of EAL and FLE children are in fact somewhat comparable by Year 5. It is important to interpret these results with caution given the reduced sample sizes resulting from analysing the year groups separately; it might be that the Year 5 group difference simply did not reach significance ($p = .093$) due to low statistical power; while the literature does show the language comprehension gap to narrow over time (e.g., Mahon & Crutchley, 2006), the results of such papers typically demonstrate a maintained significant difference between the language groups in Year 5. Further research investigating the achievement gap over the course of KS2 in a larger sample is warranted in order to clarify this uncertainty. It is important to note that these analyses are not longitudinal and thus do not demonstrate the narrowing of the vocabulary knowledge gap within a single sample of children; a different group of children was recruited for each year group at T1 and thus these results simply represent the group differences between the language groups in two samples of different ages. Chapter 6 will examine the extent to which the linguistic and cognitive abilities of both year groups changed over the course of a year and thus the group differences at the end of the year.

A further exploratory MANOVA was carried out in order to determine which measures of vocabulary were a point of weakness for the Year 3 EAL children in comparison to their FLE peers. The results of this analysis revealed that the Year 3 EAL children performed significantly lower than the Year 3 FLE children in both receptive and expressive vocabulary knowledge. This reflects findings from the literature; studies assessing both receptive and expressive vocabulary knowledge in EAL and FLE children of a similar age have typically found an EAL deficit in both (e.g., Burgoyne et al., 2011; Hutchinson et al., 2003). The current study found a greater disparity in vocabulary scores between the language groups for receptive vocabulary than for expressive vocabulary; this is also reflected in the same studies from the literature and might be explained by the age of the sample.

While significant differences in receptive and expressive vocabulary were found between the language groups in the current study, no significant difference in mathematical vocabulary knowledge was found between the groups, although the FLE group did score slightly higher on average. This is not a surprising result; previous research comparing the mathematical vocabulary knowledge of EAL and FLE children is very scarce, and while some research has found EAL children to have lower levels of mathematical vocabulary knowledge than FLE children (e.g., Powell et al., 2020), other research has found no significant difference between language-minority and monolingual children (e.g., Xu et al., 2021). It is possible that EAL and FLE children have comparable levels of mathematical vocabulary knowledge because such vocabulary is typically learnt exclusively within the school environment, which is typically equivalent for the two language groups. This is particularly pertinent for the current sample of EAL children, the majority of whom had been enrolled in English schools since the age of 4 and therefore acquired all of their mathematical vocabulary knowledge in English, together with their FLE peers. It should also be noted that within the current study, Year 3 mathematical vocabulary knowledge was assessed using a bespoke measure which was found to have an internal reliability score of $\alpha = .64$, meaning it did not necessarily reflect the true mathematical vocabulary knowledge of the participants. Indeed, the vast majority of studies measuring mathematical vocabulary knowledge seem to employ a bespoke measure, due to a lack of existing widely used standardised measures of mathematical vocabulary, making it difficult to compare the results of such studies. It would therefore be highly beneficial for future educational research if such a measure were to be developed. Replicating the current study with a standardised measure specific to the UK context and a larger sample size, while accounting for the age at which the EAL children began their English education, would help to further elucidate the levels of mathematical vocabulary knowledge in EAL children relative to those of FLE children.

Regarding the concurrent predictors of reading comprehension, both decoding and language comprehension skills were found to be significant and unique predictors for the overall sample. Language group status was not a significant predictor of reading comprehension, suggesting that the predictors of reading comprehension are similar for EAL and FLE children as hypothesised; that is, decoding and language comprehension predict reading comprehension in both language groups. This provides further support for the SVR, demonstrating that successful reading comprehension indeed relies on both decoding and language comprehension skills in both monolingual and language-minority children, and thus reflects the prevailing findings of previous research into the predictors of reading comprehension (e.g., Burgoyne et al., 2011; Gottardo & Mueller, 2009; Verhoeven & van Leeuwe, 2012). However, when further regression analyses were performed for the language groups separately in order to examine the relative strengths of each predictor, the results revealed that while both decoding and language comprehension uniquely predicted reading comprehension in the FLE group, language comprehension alone was found to be a unique significant predictor for the EAL children. Given the results of the initial regression model, the most likely explanation for this seems to be a lack of statistical power in the EAL group when running separate regression models. That is, the EAL sample in the current study consists of 28 children while the FLE group consists of 44 children, resulting in a greater loss of power for the EAL group. It is also possible that the substantial language comprehension weakness in the EAL group rendered the effect of individual differences in decoding on reading comprehension ability non-significant. Indeed, the results of the additional regression analyses did reflect the prediction that vocabulary knowledge would be a stronger predictor for the EAL children than for the FLE children, in line with some of the existing research on the subject (e.g., Babayiğit, 2014; Hutchinson et al., 2003; Verhoeven, 2000), with vocabulary knowledge uniquely accounting for 20% of the variance in reading comprehension in the EAL group compared to 11% in the FLE group. It is plausible that the elevated importance of language comprehension for reading comprehension in EAL children might suppress any potential effect of individual differences in decoding ability.

Non-verbal ability was not found to uniquely predict reading comprehension beyond the contribution of decoding and language comprehension; this is in line with results found in the literature which have found non-verbal ability to correlate with, but not uniquely predict, reading comprehension (e.g., Babayiğit, 2014; Babayiğit & Shapiro, 2020). While research has shown that verbal working memory is a unique predictor of reading comprehension in both EAL and FLE children (e.g., Lesaux et al., 2007), it was not possible to confirm the individual role of verbal working memory on reading comprehension within the current study due to the inclusion of verbal working memory in the decoding composite and the need to minimise the number of predictors tested in each model due to the limited sample size. Further research with greater scope for the inclusion of predictors due to a larger sample size should ensure to include working memory in models of reading comprehension.

An additional finding of the initial regression analysis was that the predictors of reading comprehension within the whole sample did not seem to differ according to age, suggesting that the predictors of reading comprehension are equivalent in Year 3 and Year 5. In order to investigate the prediction that the influence of decoding skills on reading comprehension decreases with age, further regression analyses were carried out, this time split by year group. The results of these analyses revealed that while both decoding and language comprehension skills predicted reading comprehension in Year 3, the influence of decoding skills was lower and non-significant in the Year 5 group. While the non-significant result might be due to the reduced sample size, these results are in line with the hypothesis that the influence of decoding skills would diminish over time due to mastery of decoding skills over the course of reading development, and with previous research into the trajectory of decoding skills as a predictor of reading comprehension (e.g., Ouellette & Beers, 2010; Tilstra et al., 2009). Again, it should be noted that these analyses are not longitudinal and thus do not provide evidence of changing predictors over time within one sample of children; the Year 3 and Year 5 groups consist of different participants and thus these results simply give a snapshot of the predictors in two different age groups. The longitudinal predictors of reading comprehension will be investigated in Chapter 6.

Finally, English use outside of school was found to be significantly associated with both vocabulary knowledge and reading comprehension in the EAL group, and regression analyses suggested that this variable indirectly predicts reading comprehension ability through vocabulary knowledge. These results are in line with the hypothesis that English use outside of school would be associated with both language comprehension and thus also reading comprehension outcomes, and is in accordance with results from the limited literature on the subject (e.g., Gathercole & Thomas, 2009; Hoff et al., 2012; Thordardottir, 2011). The results also suggest that English use outside of school is more strongly associated with vocabulary knowledge in Year 3 children than in Year 5 children. Based on these results, it seems that EAL children who rarely use English outside of school are more at risk for a weakness in English vocabulary knowledge and therefore English reading comprehension, both of which permeate many aspects of academic achievement, and that this is particularly true for younger EAL children.

Overall, the findings of this chapter are largely in line with those found in the literature. The analyses performed in this chapter provide further evidence that EAL children have significantly lower levels of language comprehension than their FLE peers while their decoding skills are comparable, and that language comprehension is the strongest predictor of reading comprehension skills in EAL children. The EAL children also exhibited lower reading comprehension skills than their FLE peers on average, reflecting results from the literature. This difference was not quite significant, but this was likely due to a reduction in sample size caused by the impact of the COVID-19 pandemic on the study. In addition, the gap in vocabulary knowledge between the language groups seemed to diminish over time, as did the contribution of decoding ability to reading comprehension in both language groups; longitudinal data to supplement these findings will be analysed and discussed in Chapter 6. The findings of this chapter confirm that a gap in linguistic ability exists between EAL and FLE children in England, suggesting that EAL children should be given further support within school to ensure their academic performance does not suffer. In particular, both receptive and expressive vocabulary knowledge should be targeted at a young age in order to reduce the vocabulary knowledge gap between EAL and FLE children and to improve reading comprehension outcomes in EAL children. In contrast, decoding skills do not need to be targeted in EAL children given the comparable decoding abilities of the language groups in the current study. Targeted support might best be delivered through 1-1 or small group sessions with EAL children during class hours, and schools should strive to regularly review the support needs of their EAL pupils in order to ensure that their needs are being met; these methods have been shown to be effective in boosting EAL academic performance (Strand et al., 2010). Additionally, the fact that language comprehension is a very strong predictor of reading comprehension in EAL children reflects the association between PiE and academic achievement seen in national performance data (e.g., Strand & Hessel, 2018) and the wide heterogeneity of the EAL population in England, as does the association between English use outside of school and language outcomes. Reintroduction of the requirement for schools to assess the PiE levels of their EAL pupils in England would allow teachers to more readily identify students who are in need of further support and would additionally allow researchers to investigate the performance of EAL children in a more pragmatic way. In order to overcome the methodological limitations of the current study, future research should replicate the study with a larger sample to confirm its findings. In addition, future research investigating the reading profiles of EAL and FLE children in England over a wider age range is recommended. In spite of its limitations, this chapter largely supports the results found in the literature, providing additional evidence that EAL children in England struggle with language comprehension in comparison to their FLE peers, and that this disadvantage is likely to contribute to difficulties with reading comprehension.

5 Mathematical Performance and its Predictors: Cross-Sectional Analysis

5.1 Introduction

National performance data from England demonstrates that in addition to literacy, EAL children seem to struggle in mathematics compared to their FLE peers (e.g., Strand et al., 2015). This chapter aims to unpick this observed achievement gap, comparing the performance of EAL and FLE children on different mathematical tasks and investigating the linguistic and cognitive predictors of their performance. Differences between the mathematical performance of EAL and FLE children in Year 3 and Year 5 are compared cross-sectionally using MANCOVA and MANOVA analyses. Specifically, performance on measures of arithmetic ability and mathematical WPS will be assessed. A series of multiple linear regression analyses will then be performed in order to determine the concurrent linguistic and cognitive predictors of mathematical performance in EAL and FLE children in Year 3 and Year 5. As in Chapter 4, no longitudinal analysis is carried out in this chapter given that the age groups contain different participants; the group differences between the language groups and the predictors of mathematical performance will simply be observed for each year group separately.

As mentioned above, national performance data demonstrates a mathematical achievement gap between EAL and FLE children in England. The data shows this EAL disadvantage to narrow and eventually disappear with age, however a modest achievement gap remains throughout primary school. Furthermore, a strong relationship between the PiE levels of EAL children and their mathematical performance has been identified (e.g., Strand & Hessel, 2018), with EAL children in the first two PiE stages underperforming substantially in mathematics relative to their monolingual peers and those in the highest two PiE stages actually outperforming the monolingual group. This evidence demonstrates how the interpretation of national data comparing the academic performance of EAL and FLE children based on EAL status alone is misleading; the achievement gap is in reality far wider for EAL children with low levels of PiE, and thus many children are more critically in need of support than the national figures might suggest. In addition, the clear link between PiE and mathematical achievement in EAL children suggests that the language weaknesses commonly found in EAL children are at the root of their mathematical disadvantage.

Research has indeed shown a clear link between language skills and mathematical performance, both in EAL and other language-minority children specifically as well as in monolingual populations. As discussed in detail in Section 2.1, language skills are vital to core aspects of numerical cognition such as counting and number recognition (e.g., LeFevre et al., 2010). Regarding specific mathematical tasks, research has found phonological processing skills to contribute significantly to performance on measures of arithmetic ability involving arithmetic computation (e.g., Bjork & Bowyer-Crane, 2013) and arithmetic fluency (e.g., De Smedt et al., 2010). In contrast, language comprehension skills have been found to predict performance solely on mathematical tasks involving verbal language, such as mathematical word problems (e.g., Fuchs et al., 2006; Xu et al., 2021). In addition, reading comprehension, a well-established area of weakness for EAL children, has been found to be a strong predictor of performance on mathematical word problems (e.g., Bjork & Bowyer-Crane, 2013; Trakulphadetkrai et al., 2017).

Given that the literature has established that the key disadvantage faced by EAL children relative to FLE children is in language comprehension and reading comprehension (e.g., Hutchinson et al., 2003; Melby-Lervåg and Lervåg, 2014), it is not surprising that research has shown their mathematical weaknesses to stem from this disadvantage. That is, while the literature on mathematical performance in EAL children is small compared to the literature surrounding their literacy profiles, research has typically found EAL or language-minority children to perform significantly lower than monolingual children on WPS tasks, which rely on language and reading comprehension, but not on tests of arithmetic ability (e.g., Abedi & Lord, 2001; Trakulphadetkrai et al., 2017; Xu et al., 2021), of which the only salient linguistic predictor is phonological decoding which is not an area of systematic weakness for EAL children. Considered together, this evidence suggests that the main area of mathematical weakness for EAL children is in WPS, and that this is likely to be a direct result of their language comprehension disadvantage.

Research comparing the predictors of mathematical performance between EAL and FLE children is very limited. Across research carried out with monolingual children, the key predictors of arithmetic computation have been commonly identified as phonological skills, working memory, attention and processing speed (e.g., Fuchs et al., 2008), and the key predictors of WPS have been commonly identified as arithmetic computation, language or reading comprehension skills, working memory and non-verbal ability (e.g., Spencer et al., 2020). Recent research has also started to investigate the contribution of mathematical vocabulary knowledge to WPS (e.g., Lin, 2021; Peng & Lin, 2019; Xu et al., 2021). The limited evidence assessing these predictors in EAL or other language-minority children suggests that on the whole, the predictors of both arithmetic ability and WPS are somewhat comparable across the language groups (e.g., Foster et al., 2018; Xu et al., 2021), although the results are somewhat unclear given that different variables are often assessed across the studies. Notwithstanding, Xu and colleagues found both receptive vocabulary knowledge and working memory to be stronger predictors of WPS in language-minority children than in monolingual children. In addition, Xu and colleagues found mathematical vocabulary knowledge to significantly predict WPS over and above the contribution of receptive vocabulary knowledge in monolingual children only. Trakulphadetkrai and colleagues (2017) also investigated the predictors of WPS in both EAL and FLE children, and also found that the influence of comprehension skills on WPS was greater for the EAL group.

Very little research exists which compares the concurrent predictors of WPS across different age groups. In fact, only one study was found which did this: a meta-analysis of the predictors of WPS by Lin (2021). After identifying the predictors of WPS for the overall sample across 98 studies, Lin split the sample into younger (Kindergarten to Grade 2; ages 5-8) and older (Grade 3 to Grade 5; ages 8-11) groups and assessed the predictors of WPS for each group separately. The results of these analyses showed the predictors of WPS in the older group to be very typical of the commonly identified predictors in the literature; that is, arithmetic computation, language comprehension, mathematical vocabulary knowledge, working memory, attention and non-verbal ability were identified as unique predictors. In contrast, only arithmetic ability and attention were found to uniquely predict WPS in the younger age group, ostensibly due to the less complex nature of the mathematical word problems typically encountered by these younger year groups. It is unclear how relevant these findings will be to the results of the current study, given that the youngest primary year groups are not represented in the current study; it is likely that the current study will show less of a distinction between the year groups due to their relative closeness in age as well as the similarity in complexity of the two bespoke WPS tasks. In addition, the study by Lin was carried out with monolingual children, thus giving no indication of the effect of age in EAL children.

Taking the discussed research into account, there is a clear need for UK-based research investigating the areas of mathematical weakness for EAL children in comparison to their FLE peers, as well the predictors of performance on different mathematical tasks in EAL and FLE children. This will help to identify the nature of the mathematical achievement gap observed between EAL and FLE children in England, as well as the underlying reasons for this gap, and thus how to support EAL children in mathematics most effectively. Specifically, research should seek to clarify the role of comprehension skills in the mathematical performance of EAL and FLE children in England, as well as how the predictors of mathematical ability within the two language groups might differ with age. The current chapter addresses these research gaps, investigating the mathematical performance of EAL children relative to their FLE peers in a sample of Year 3 and Year 5 children from English primary schools, and aiming to clarify the relative roles of various linguistic and cognitive skills in the arithmetic computation and mathematical WPS abilities of both groups.

Given that the current study aims to examine a wide range of skills in relation to mathematical performance which are likely to overlap in some way (for example, decoding skills are key predictors of both reading comprehension and arithmetic computation which in turn are both vital to mathematical WPS), this thesis makes a distinction between academic and cognitive or linguistic predictors of mathematical ability and examines these separately; an approach also taken by Lin (2021). Specifically, the academic predictors to be examined are reading comprehension and arithmetic ability, and the cognitive or linguistic predictors to be examined are general vocabulary knowledge, mathematical vocabulary knowledge, decoding ability and non-verbal ability. This approach will allow the roles of the overarching academic skills to be assessed before separately examining the individual contributions of the underlying cognitive or linguistic skills.

5.1.1 Research Questions and Hypotheses

This chapter addresses research questions 4 and 5 as laid out in Section 2.5. These are:

4. How do the arithmetic and mathematical WPS abilities of EAL children compare to those of FLE children in Year 3 and Year 5?
5. Which cognitive, linguistic and academic skills concurrently predict arithmetic computation and mathematical WPS in EAL and FLE children in Year 3 and Year 5?

Regarding research question 4, taking the discussed literature into account, it is hypothesised that the EAL children will score significantly lower than the FLE children on the bespoke measure of WPS, but that there will be no significant difference between the language groups on scores of arithmetic ability. Given that the bespoke arithmetic computation task and the bespoke WPS task were designed as parallel tasks containing the same mathematical calculations within their items, it is also hypothesised that the difference between performance on the bespoke tasks, and thus the effect of contextualising the calculations into mathematical word problems, will be significantly greater for the EAL group. In line with the observed diminution of the mathematical achievement gap between EAL and FLE children in England, it is hypothesised that the difference in WPS scores will be smaller for the Year 5 group than for the Year 3 group.

Regarding research question 5, it is expected that the unique predictors of mathematical ability will be comparable for the two language groups. Specifically, it is hypothesised that of the skills measured in the current study, the only unique academic predictor of arithmetic computation will be arithmetic fluency, and the only unique cognitive or linguistic predictor of arithmetic computation will be decoding ability. It is hypothesised that both reading comprehension and arithmetic ability will emerge as unique academic predictors of WPS ability, and that the unique cognitive or linguistic predictors of WPS will be general vocabulary knowledge, mathematical vocabulary knowledge, decoding skills and non-verbal ability. It is also anticipated that while the unique predictors of WPS will be comparable between the language groups, reading comprehension and language comprehension will be stronger predictors for the EAL group. Finally, it seems likely that the predictors of mathematical ability will be largely comparable between the Year 3 and Year 5 groups given the proximity of the ages, however it is acknowledged that due to the scarcity of previous research on the subject, these analyses will be exploratory and thus no firm hypotheses can be made regarding their results.

5.2 Method

5.2.1 Design and Participants

This chapter analyses the remaining data collected at T1 for the current study, the design of which can be found in Section 3.2.1. This chapter uses the same sample as Chapter 4, which consists of 72 participants recruited from the five schools described in Section 3.3.1. As in Chapter 4, all initial analyses carried out in the current chapter combined the Year 3 and Year 5 children into one sample and used year group as a covariate, in order to maximise statistical power due to the reduced sample size caused by the COVID-19 pandemic. Accordingly, demographic information for the combined sample as well as for the Year 3 and Year 5 groups separately is presented in Table 5.1. As stated in Sections 4.2.1 and 3.3.2, neither the EAL and FLE groups within the combined sample nor within the separate year groups differed significantly in their age, gender distribution or FSM eligibility. In addition, the L1s of the EAL participants are reported in Section 3.3.2.

Table 5.1
T1 participant demographics

	Year 3	Year 5	Combined sample
N	33	39	72
% EAL	45.4%	33.3%	38.9%
% FSM	27.2%	17.9%	22.2%
% Male	51.1%	33.3%	41.7%
Mean age in months (*SD*)	92.82 (4.78)	118.00 (4.11)	106.46 (13.38)

5.2.2 Measures

The primary measures used to collect the data to be analysed in the current chapter were the mathematical T1 measures listed and detailed in Section 3.4. In addition, the majority of the linguistic and cognitive measures collected at T1, and previously analysed in Chapter 4, were also used in the current chapter as independent variables in a series of multiple regression analyses investigating the predictors of mathematical ability, either independently or as components of composite variables. The complete list of measures analysed in this chapter can be seen in Table 5.2.

Table 5.2
T1 test battery; all measures

Skill	Measure
Mathematical Skills	
Arithmetic Fluency	Addition, Addition with Carry, Subtraction, Subtraction with Carry, Multiplication; TOBANS
Arithmetic Computation	Bespoke task
Mathematical WPS	Bespoke task
Passage Reading	
Reading Comprehension	YARC
Reading Accuracy	YARC
Reading Rate	YARC
Decoding Skills	
Word Reading	DTWRP
Phonological Awareness	Phoneme Isolation; CTOPP-2
Speed of Lexical Access	Rapid Digit Naming & Rapid Letter Naming; CTOPP-2
Phonological Memory	Memory for Digits; CTOPP-2
Vocabulary	
Receptive Vocabulary	BPVS3
Expressive Vocabulary	Vocabulary; WASI-II
Mathematical Vocabulary	Bespoke task
Cognitive Skills	
Verbal Working Memory	Backward Digit Recall; WMTB-C
Non-verbal Ability	Matrix Reasoning; WASI-II

5.2.3 Procedure

The T1 mathematical performance data was collected alongside the T1 linguistic and cognitive data and thus the procedure was identical to that of Chapter 4, following the general procedure and testing schedule described in Section 3.6. The mathematical measures were spread out across the two testing sessions for each participant, and it should be noted that the bespoke parallel tasks were carried out in different sessions for all participants, at least one week apart, in order to minimise the likelihood of participants detecting the parallel nature of the tasks or remembering answers between sessions.

5.3 Results

5.3.1 Descriptive Statistics: Mathematical Skills

The current study employed three tests of mathematical ability; the bespoke arithmetic computation task, the parallel bespoke WPS task and the TOBANS, which assesses arithmetic fluency. A fourth mathematical variable equalling the difference between each participant's scores on the two parallel bespoke tasks was calculated by subtracting each participant's WPS score from their arithmetic computation score. Because the two bespoke tasks required the participants to perform the same mathematical calculations, the difference in scores represents the possible effect that the contextualisation of the calculations into word problems and thus the presence of verbal language in the items had on performance for each participant. A positive score on this variable translates to better performance on the arithmetic task, while a negative score translates to better performance on the WPS task.

Table 5.3 presents descriptive statistics for the mathematical variables. Based on the skewness and kurtosis scores of the measures, there was no concern regarding normality for any of the four variables and therefore no transformations were required.

Table 5.3
Descriptive statistics for the T1 mathematical measures; whole sample

Measure	Mean	*SD*	Skewness	Kurtosis
Arithmetic Computation	15.90	7.66	-0.02	-1.01
Mathematical WPS	15.72	7.62	-0.28	-0.81
Difference in Scores on Bespoke Tasks	0.19	3.29	0.08	0.91
Arithmetic Fluency	73.97	31.28	0.67	0.89

Table 5.4 presents descriptive statistics for the EAL and FLE children, for the combined sample as well as for the year groups separately. The whole sample means demonstrate that the FLE children outperformed the EAL children on both bespoke mathematical measures, by 0.89 points on the arithmetic computation task and by 2.01 points on the WPS task. Regarding the difference in scores on the bespoke tasks, the EAL group showed a reduction in scores from the arithmetic computation to the WPS task, while the FLE group scored marginally better, on average, on the WPS task. Finally, the EAL group outperformed the FLE group on the arithmetic fluency task.

The language group differences for the combined sample are somewhat reflected in those shown for each year group. In both cases, the Year 5 group differences for the bespoke tasks reflect those of the combined sample, while the Year 3 group differences show an EAL advantage on both bespoke tasks, although the EAL advantage on the WPS task is very slight. The Year 3 statistics for the difference in performance on the bespoke tasks reflect those of the combined sample, while the contextualisation of the arithmetic problems into mathematical word problems seems to have a comparable effect on the two language groups in Year 5. As in the combined sample, the EAL children appear to outperform the FLE children on arithmetic fluency in both year groups. The group differences presented in Table 5.4 will be tested inferentially in Section 5.3.3.

Table 5.4
Mean (SD) raw T1 mathematical scores split by language group; whole sample, Year 3 and Year 5

Measure	Whole sample		Year 3		Year 5	
	EAL	FLE	EAL	FLE	EAL	FLE
Arithmetic Computation	15.36	16.25	10.33	7.39	21.15	22.38
	(6.34)	(8.44)	(2.26)	(3.76)	(4.06)	(4.16)
Mathematical WPS	14.49	16.50	9.12	8.94	20.69	21.73
	(6.98)	(7.98)	(4.16)	(5.59)	(3.38)	(4.30)
Difference in Scores on	0.86	-0.25	1.21	-1.55	0.46	0.66
Bespoke Tasks	(3.12)	(3.34)	(3.64)	(3.09)	(2.44)	(3.24)
Arithmetic Fluency	77.51	71.72	65.95	50.03	90.85	86.74
	(24.86)	(34.80)	(17.48)	(20.76)	(25.97)	(34.82)

In order to give an indication of how the mathematical performance of the EAL and FLE children compared before multiple imputation was carried out, the equivalent statistics using pairwise deletion on the original mathematical data are presented in Appendix 16. No substantial differences between the sets of descriptive statistics are evident. For this reason, it seems unlikely that the use of multiple imputation will have meaningfully influenced the results of the mathematical group comparisons beyond boosting their statistical power.

5.3.2 Correlations between the Mathematical Variables and the Creation of an Arithmetic Composite

In order to investigate the relationships between the mathematical variables, partial correlations, controlling for year group, were calculated and are presented in Table 5.5. As can be seen from the results of the partial correlation analyses, all three mathematics tasks were strongly intercorrelated. Firstly, a strong positive correlation was found between performance on each of the two bespoke tasks. Despite the fact that these tasks measured different skills, this result is not surprising, given the parallel nature of the tasks as well as the established role of arithmetic computation in WPS. As also expected, arithmetic fluency was strongly correlated with both bespoke measures, but more strongly with the arithmetic computation task. The difference between scores on the two bespoke tasks was significantly correlated with scores on the mathematical WPS task; this was to be expected given how the difference scores were calculated. Correlations between the mathematical variables using pairwise deletion on the original mathematical data can be found in Appendix 17; again, these results are very similar to those presented in Table 5.5, suggesting that the use of multiple imputation did not meaningfully influence the relationships between the linguistic and cognitive variables present in the original data.

Table 5.5
Partial correlations between the T1 mathematics measures, controlling for year group

	1.	2.	3.	4.
1. Arithmetic Computation				
2. Mathematical WPS	.70***			
3. Difference in Scores on Bespoke Tasks	.22	-.55***		
4. Arithmetic Fluency	.72***	.62***	-.00	

Note. * indicates $p < .05$, ** indicates $p < .01$, *** indicates $p < .001$

After the partial correlations between the variables had been examined, it was decided that an "Arithmetic" composite variable, comprising the arithmetic computation and arithmetic fluency scores for each participant, would be created. These two variables were chosen to be combined due to the fact that they were highly correlated as well as theoretically linked, while it was assumed that scores on the two bespoke tasks were highly correlated largely due to their parallel item content. Creating the arithmetic composite reduced the number of variables to be entered into the forthcoming MANCOVA and MANOVA analyses and helped to avoid the presence of multicollinearity in the data. The composite variable was created by converting scores on the two relevant tasks to standardised *z*-scores, and subsequently taking the mean of these *z*-scores for each participant. The mean score on this composite across the full sample was 0.00 (0.93) and the composite variable was found to be normally distributed with a pooled skewness value of 0.32 and a pooled kurtosis value of -0.10.

5.3.3 EAL and FLE Differences on the Mathematical Measures

In order to compare the mathematical skills of the EAL and FLE children and thus answer research question 4, a series of one-way MANCOVA and MANOVA analyses were performed. As in

Section 4.3.3., an initial MANCOVA was carried out on the whole sample, with year group as a covariate, in order to boost the sample size for the analysis and thus its statistical power. The outcome variables entered into the model were the arithmetic composite, mathematical WPS and the difference in scores between performance on the two bespoke tasks.

The assumptions of performing a MANCOVA were checked prior to the analysis. There was no evidence of multicollinearity between the outcome variables or the covariate, with all correlations falling below $r = .90$, and all relationships between the outcome variables and the covariate were linear. Homogeneity of variances was evident for all outcome variables; Levene's test was non-significant for all outcome variables across all five imputations. The assumption of homogeneity of covariance was also met, according to the results of Box's M test, with non-significant results evident across all five imputations.

The results of the MANCOVA are presented in Table 5.6. The MANCOVA did not show a significant effect of language group on the combined mathematics outcome measures, $V = .08$, $F(3, 29.95) = 2.04$, $p = .130$, but did reveal a significant effect of year group on the outcome measures, $V = .81$, $F(3, 64.12) = 97.80$, $p < .001$. As shown in Table 5.6, there was no significant difference between the language groups on any of the mathematics variables.

Table 5.6
MANCOVA results for the T1 mathematical variables; combined year groups

Variable	EAL Mean	FLE Mean	*F*	*p*	Effect Size [95% CIs]
Arithmetic Composite	0.02 (0.76)	-0.01 (1.04)	1.65	.205	-0.04 [-0.51, 0.44]
Mathematical WPS	14.49 (6.98)	16.50 (7.98)	0.01	.918	0.26 [-0.21, 0.74]
Difference in Scores on Bespoke Tasks	0.86 (3.12)	-0.25 (3.34)	1.60	.217	-0.34 [-0.82, 0.14]

Note: Effect Size is Cohen's *d* with 95% Confidence Intervals [Lower Limit, Upper Limit].

Given that a strong effect of year group was found on the combined outcome measures, exploratory MANOVAs were performed for each year group separately in order to investigate how the mathematical performance of the language groups differed in Year 3 and Year 5. The results of these exploratory analyses are presented in Table 5.7. While the assumptions for MANOVA were met, these results should again be interpreted with caution due to the resulting reduction in sample size for each analysis.

For the Year 3 group, there was a significant effect of language group on scores on the mathematical outcome variables, $V = .43$, $F(3, 13.63) = 10.25$, $p < .001$. As shown in Table 5.7, the

EAL children significantly outperformed the FLE children on the arithmetic composite, $F(1, 28.71) = 7.14$, $p = .012$, with a large effect size. In addition, the average difference in scores between the bespoke tasks was significantly greater for the EAL children, $F(1, 16.29) = 6.02$, $p = .026$, also with a large effect size.

For the Year 5 group, there was no significant effect of language group on the combined outcome variables, $V = .09$, $F(3, 24.07) = 1.25$, $p = .314$. As can be seen in Table 5.7, there was also no significant effect of language group on any of the three individual outcome variables.

Table 5.7

MANOVA results for the T1 mathematical variables; separate year groups

Variable	Year 3					Year 5				
	EAL Mean	FLE Mean	*F*	*p*	Effect Size [95% CIs]	EAL Mean	FLE Mean	*F*	*p*	Effect Size [95% CIs]
Arithmetic Composite	-0.49	-0.94	7.14	.012	-0.94	0.61	0.63	0.03	.855	0.02
	(0.37)	(0.55)			[-1.66, -0.21]	(0.64)	(0.78)			[-0.65, 0.68]
Mathematical WPS	9.12	8.94	0.02	.899	-0.04	20.69	21.73	0.50	.484	0.26
	(4.16)	(5.59)			[-0.72, 0.65]	(3.38)	(4.30)			[-0.41, 0.92]
Difference in Scores on	1.21	-1.55	6.02	.026	-0.83	0.46	0.66	0.05	.834	0.06
Bespoke Tasks	(3.64)	(3.09)			[-1.54, -0.10]	(2.44)	(3.24)			[-0.60, 0.73]

Note: Effect Size is Cohen's *d* with 95% Confidence Intervals [Lower Limit, Upper Limit].

5.3.3.1 Summary

In summary, the analyses presented in this section showed few differences between the EAL and FLE children in terms of mathematical performance. When the year groups were combined, no significant differences were found in the EAL and FLE children's scores on the arithmetic composite, mathematical WPS nor the difference in performance between scores on the two bespoke tasks. Exploratory MANOVAs, which should be interpreted with caution, suggested that while the mathematical abilities of the EAL and FLE children in Year 5 did not differ significantly, the Year 3 EAL children outperformed the Year 3 FLE children on the arithmetic composite variable, and also showed a significantly greater difference in scores on the two bespoke mathematical tasks.

5.3.4 The Concurrent Predictors of Arithmetic Computation and Mathematical WPS

In order to assess the concurrent predictors of mathematical ability in EAL and FLE children and therefore answer research question 5, a series of correlation and multiple linear regression analyses were carried out; these are presented in the following subsections. Specifically, the contributions of reading comprehension, arithmetic fluency, general vocabulary knowledge, mathematical vocabulary knowledge, decoding ability and non-verbal ability to arithmetic computation and mathematical WPS were examined. It should be noted that while the predictors of arithmetic computation and WPS identified in the literature differ somewhat, it was decided that the same predictors should be examined for each bespoke measure in order to allow direct comparison of the predictors between the parallel tasks as well as across the language groups. Given that this thesis places a larger focus on mathematical WPS than on arithmetic computation due to the comprehension disadvantage faced by EAL children and the established role of comprehension skills in WPS, the predictors assessed for each bespoke task emulated those identified as the key predictors of WPS in the literature as far as possible. Decoding ability was chosen to be included in the cognitive and linguistic models due to its link to both reading comprehension and arithmetic computation. In the interest of limiting the number of predictor variables entered into the models and thus maximising statistical power, the decoding composite created in Section 4.3.2 was used. Given that the decoding composite included phonological skills and verbal working memory, these were not entered separately into any analyses despite their established links with arithmetic computation and WPS, again reducing the number of predictors to be entered into each model and thus preventing problems with multicollinearity.

Although the literature has typically identified arithmetic computation as a predictor of WPS, it was not viable to include the bespoke measure of arithmetic computation in the proceeding regression models given that it was to be used as an outcome measure as well as the parallel nature of the tasks. Instead, arithmetic fluency was used as a proxy for general arithmetic computation ability in all mathematical regression models.

Given that the role of mathematical vocabulary knowledge was to be examined separately to that of general vocabulary knowledge, the vocabulary composite created in Section 4.3.2 could not be used; instead, a new “General Vocabulary” composite was created by taking the mean of the *z*-scores for receptive vocabulary knowledge and expressive vocabulary knowledge for each participant and was used in the subsequent analyses. The mean (*SD*) score across the whole sample for this variable was 0.00 (0.95), and the variable was found to have a normal distribution, with a pooled skewness value of -0.39 and a pooled kurtosis value of 0.26.

5.3.4.1 The Concurrent Predictors of Mathematical Ability: Combined Sample

In the interest of maximising statistical power, the predictors of each outcome variable were initially examined for the whole sample, controlling for year group. Table 5.8 presents partial correlations, controlling for year group, between the predictors of interest and performance on the bespoke mathematical tasks for the combined sample.

Table 5.8
Partial correlations, controlling for year group, between the predictors of interest and mathematical performance

	Arithmetic Computation	Mathematical WPS
Academic Skills		
Reading Comprehension	.53***	.51***
Arithmetic Fluency	.72***	.62***
Cognitive or Linguistic Skills		
General Vocabulary	.43***	.53***
Mathematical Vocabulary	.53***	.46***
Decoding	.54***	.53***
Non-verbal Ability	.33**	.21

Note. * indicates $p < .05$, ** indicates $p < .01$, *** indicates $p < .001$

Subsequently, multiple linear regression models for each outcome variable were tested using the combined sample, entering both year group and language group status into the models to indicate whether the predictors differed for the Year 3 and Year 5 children or for the EAL and FLE children. Thus, the eventual predictors entered into each model examining the academic predictors were year group, language group, reading comprehension and arithmetic fluency, while the eventual predictors entered into each model examining the cognitive and linguistic predictors were year group, language group, general vocabulary knowledge, mathematical vocabulary knowledge, decoding and non-verbal ability. Prior to these analyses, the assumptions of multiple linear regression were checked, and no violations of the assumptions were apparent.

The results of the multiple regression analyses predicting arithmetic computation are presented in Table 5.9. Model 1 significantly accounted for 90% of the variance in arithmetic computation, $F(4, 63.56) = 107.79$, $p < .001$. Both reading comprehension and arithmetic fluency were found to uniquely predict arithmetic computation, uniquely accounting for 2% and 7% of the variance in arithmetic computation. In addition, year group was found to be a significant predictor while language group was not, suggesting that the academic predictors of arithmetic computation differ between Year 3 and Year 5 children but not between EAL and FLE children.

Model 2 significantly accounted for 86% of the variance in arithmetic computation scores, $F(6, 63.01) = 71.80$, $p < .001$. Mathematical vocabulary knowledge and decoding ability were found to uniquely predict arithmetic computation in the combined sample, while general vocabulary knowledge and non-verbal ability did not. In addition, both year group and language group contributed significantly to the model, suggesting that the cognitive and linguistic predictors of arithmetic computation differ between Year 3 and Year 5 children, as well as between EAL and FLE children.

Table 5.9
Multiple regression models predicting arithmetic computation; whole sample

Predictor	Adjusted R^2	β (*SE*)	*t*	*p*	Unique R^2
Model 1: Academic Predictors	.90				
Year Group		.61 (.05)	12.53	< .001	.25
Language Group		.04 (.04)	0.87	.384	< .01
Reading Comprehension		.19 (.05)	3.82	< .001	.02
Arithmetic Fluency		.33 (.05)	6.54	< .001	.07
Model 2: Cognitive & Linguistic Predictors	.86				
Year Group		.31 (.13)	2.36	.018	.01
Language Group		.11 (.05)	2.04	.041	< .01
General Vocabulary		.10 (.08)	1.25	.212	< .01
Mathematical Vocabulary		.40 (.17)	2.40	.017	.01
Decoding		.18 (.06)	3.00	.003	.02
Non-verbal Ability		.09 (.05)	1.61	.108	< .01

Note. Unique R^2 is represented by squared semi-partial correlations

The results of the multiple regression models predicting mathematical WPS are shown in Table 5.10. Model 1 was found to significantly account for 81% of the variance in mathematical WPS, $F(4, 36.14) = 17.98$, $p < .001$. Both reading comprehension and arithmetic fluency were found to significantly predict mathematical WPS, uniquely accounting for 2% and 7% of the total variance in WPS scores respectively. In addition, year group significantly contributed to the model while language group did not, suggesting that the academic predictors of WPS differ between the Year 3 and the Year 5 children but not between the EAL and FLE children.

Model 2 significantly predicted 79% of the variance in mathematical WPS, $F(6, 44.73) = 17.03$, $p < .001$. General vocabulary knowledge and decoding ability were found to significantly predict WPS scores, each uniquely accounting for 3% of the variance in WPS, while mathematical vocabulary knowledge and non-verbal ability were not. Again, year group was found to be a significant predictor while language group was not, suggesting that the cognitive and linguistic predictors of WPS are comparable for EAL and FLE children but not for Year 3 and Year 5 children.

Table 5.10
Multiple regression models predicting mathematical WPS; whole sample

Predictor	Adjusted R^2	β (*SE*)	*t*	*p*	Unique R^2
Model 1: Academic Predictors	.81				
Year Group		.54 (.07)	8.04	< .001	.19
Language Group		-.04 (.06)	-0.68	.498	< .01
Reading Comprehension		.20 (.07)	3.01	.003	.02
Arithmetic Fluency		.35 (.07)	4.88	< .001	.07
Model 2: Cognitive & Linguistic Predictors	.79				
Year Group		.42 (.17)	2.54	.011	.02
Language Group		.04 (.07)	0.52	.607	< .01
General Vocabulary		.28 (.11)	2.50	.016	.03
Mathematical Vocabulary		.11 (.21)	0.51	.610	< .01
Decoding		.25 (.07)	3.31	< .001	.03
Non-verbal Ability		.01 (.07)	0.10	.921	< .01

Note. Unique R^2 is represented by squared semi-partial correlations

5.3.4.2 The Concurrent Predictors of Mathematical Ability by Language Group

Following the initial analyses using the combined sample, further multiple regression models were run for each language group separately while continuing to control for year group. Although a significant effect of language group was found for the cognitive and linguistic predictors of arithmetic computation only using the combined sample, further analyses by language group allowed the strength of each predictor in EAL and FLE children to be compared. Aside from the exclusion of language group as a predictor variable, the models tested were identical to those tested on the combined sample and continued to examine the academic and cognitive or linguistic predictors of mathematical ability separately. Given the reduced sample sizes caused by running the analyses separately for each language group, the results of these analyses should be interpreted with caution. The partial correlations, controlling for year group, between the predictor variables and performance on the bespoke mathematical tasks for the EAL and FLE children are presented in Table 5.11.

Table 5.11
Partial correlations, controlling for age, between the predictors of interest and mathematical performance; separate language groups

	Arithmetic Computation		Mathematical WPS	
	EAL	FLE	EAL	FLE
Academic Skills				
Reading Comprehension	.36	.69***	.47*	.54***
Arithmetic Fluency	.65***	.74***	.60***	.66***
Cognitive & Linguistic Skills				
General Vocabulary	.44*	.68***	.65***	.56***
Mathematical Vocabulary	.43*	.69***	.42*	.50***
Decoding	.33	.65***	.33	.65***
Non-verbal Ability	.36	.36*	.13	.24

Note. * indicates $p < .05$, ** indicates $p < .01$, *** indicates $p < .001$

The results of the multiple regression analyses predicting arithmetic computation for the language groups separately are shown in Table 5.12. For the FLE children, Model 1 was found to significantly account for 92% of the variance in arithmetic computation, $F(3, 37.37) = 114.77$, $p < .001$. Reading comprehension and arithmetic fluency were both found to significantly predict arithmetic computation, uniquely accounting for 3% and 5% of the total variance respectively. In addition, year group was found to be a significant predictor, suggesting that the academic predictors of arithmetic computation in FLE children differ between Year 3 and Year 5. Model 2 significantly accounted for 93% of the variance in the arithmetic computation scores of the FLE group, $F(5, 35.92) = 90.41$, $p < .001$. General vocabulary knowledge, mathematical vocabulary knowledge and decoding ability were all found to significantly predict arithmetic computation, uniquely accounting for 2%, 1% and 2% of the variance in arithmetic computation, while non-verbal ability was not found to be a significant predictor. Year group was also not found to be a significant predictor, suggesting that for FLE children, the linguistic and cognitive predictors of arithmetic computation are comparable between Year 3 and Year 5.

For the EAL children, Model 1 was found to significantly account for 85% of the variance in arithmetic computation, $F(3, 22.15) = 49.96$, $p < .001$. Arithmetic fluency was found to significantly predict arithmetic computation, accounting uniquely for 8% of the total variance, while reading comprehension was not a significant predictor. Additionally, year group was found to be a significant predictor, again suggesting that the academic predictors of arithmetic computation in EAL children differ for Year 3 and Year 5 children. For the EAL children, Model 2 significantly accounted for 79% of the variance in arithmetic computation, $F(5, 20.24) = 21.08$, $p < .001$. No cognitive or linguistic variables were found to uniquely predict arithmetic computation for the EAL group. However, year group did significantly contribute to the model, suggesting that the cognitive and linguistic predictors of arithmetic computation in EAL children differ somewhat between Year 3 and Year 5.

Table 5.12

Multiple regression models predicting arithmetic computation; separate language groups

Predictor	EAL					FLE				
	Adjusted R^2	β (*SE*)	*t*	*p*	Unique R^2	Adjusted R^2	β (*SE*)	*t*	*p*	Unique R^2
Model 1 - Academic Predictors	.85					.92				
Year Group		.64 (.09)	7.09	< .001	.28		.61 (.06)	11.15	< .001	.25
Reading Comprehension		.12 (.09)	1.44	.150	.01		.23 (.06)	3.90	< .001	.03
Arithmetic Fluency		.35 (.09)	3.90	< .001	.08		.29 (.06)	4.90	< .001	.05
Model 2 - Cognitive & Linguistic Predictors	.79					.93				
Year Group		.49 (.25)	1.97	.048	.03		.24 (.13)	1.84	.066	< .01
General Vocabulary		.14 (.18)	0.74	.458	< .01		.21 (.06)	3.34	< .001	.02
Mathematical Vocabulary		.19 (.34)	0.57	.566	< .01		.44 (.16)	2.78	.005	.01
Decoding		.08 (.12)	0.64	.522	< .01		.20 (.06)	3.29	.001	.02
Non-verbal Ability		.16 (.10)	1.55	.122	.02		.00 (.05)	0.03	.974	< .01

Note. Unique R^2 is represented by squared semi-partial correlations

Table 5.13 presents the results of the multiple regression analyses predicting mathematical WPS for the EAL and FLE children separately. For the FLE children, Model 1 significantly accounted for 80% of the variance in mathematical WPS, $F(3, 32.59) = 28.78$, $p < .001$. Both reading comprehension and arithmetic fluency significantly predicted mathematical WPS, uniquely accounting for 2% and 7% of the variance in WPS respectively. In addition, year group was found to be a significant predictor, showing the academic predictors of mathematical WPS in FLE children to differ between Year 3 and Year 5. Model 2 significantly accounted for 81% of the variance in mathematical WPS for the FLE group, $F(5, 30.12) = 16.84$, $p < .001$. General vocabulary knowledge and decoding ability were both found to significantly predict mathematical WPS, uniquely accounting for 3% and 6% of the total variance in WPS, while mathematical vocabulary knowledge and non-verbal ability were not. Furthermore, year group was not found to be a significant predictor, suggesting that the linguistic and cognitive predictors of mathematical WPS in FLE learners are do not differ between Year 3 and Year 5.

For the EAL children, Model 1 was found to significantly account for 82% of the variance in mathematical WPS, $F(3, 13.25) = 5.76$, $p = .010$. As for the FLE children, both reading comprehension and arithmetic fluency significantly predicted WPS in the EAL group, uniquely accounting for 3% and 7% of the variance in WPS respectively. Again, year group was found to be a significant predictor, suggesting that the academic predictors of mathematical WPS differ for Year 3 and Year 5 EAL children. Model 2 significantly accounted for 80% of the variance in mathematical WPS for the EAL children, $F(5, 14.97) = 5.35$, $p = .005$. General vocabulary knowledge was identified as a significant predictor of mathematical WPS, uniquely accounting for 7% of the variance in WPS, while mathematical vocabulary knowledge, decoding ability and non-verbal ability were not found to be significant predictors. However, year group made a significant contribution to the model, suggesting that there is a difference in the linguistic and cognitive predictors of WPS between Year 3 and Year 5 EAL children.

Table 5.13

Multiple regression models predicting mathematical WPS; separate language groups

Predictor	EAL					FLE				
	Adjusted R^2	β (*SE*)	*t*	*p*	Unique R^2	Adjusted R^2	β (*SE*)	*t*	*p*	Unique R^2
Model 1 - Academic Predictors	.82					.80				
Year Group		.59 (.11)	5.43	< .001	.24		.51 (.10)	5.25	< .001	.17
Reading Comprehension		.21 (.09)	2.21	.027	.03		.19 (.09)	2.07	.038	.02
Arithmetic Fluency		.32 (.10)	3.32	< .001	.07		.37 (.10)	3.58	< .001	.07
Model 2 - Cognitive & Linguistic Predictors	.80					.81				
Year Group		.70 (.26)	2.70	.007	.06		.31 (.23)	1.34	.183	< .01
General Vocabulary		.53 (.19)	2.70	.008	.07		.24 (.12)	2.02	.050	.03
Mathematical Vocabulary		-.23 (.35)	-0.64	.520	< .01		.18 (.29)	0.63	.530	< .01
Decoding		.02 (.12)	0.14	.887	< .01		.34 (.09)	3.64	< .001	.06
Non-verbal Ability		.02 (.11)	0.17	.868	< .01		-.02 (.09)	-0.26	.798	< .01

Note. Unique R^2 is represented by squared semi-partial correlations

5.3.4.3 The Concurrent Predictors of Mathematical Ability by Year Group

In light of the fact that year group was found to have a significant effect on the predictors of mathematical ability within the combined sample, further multiple regression models were also run for each year group separately, with the language groups combined, in order to investigate the predictors of mathematical ability separately for the Year 3 and Year 5 children. The models tested were identical to those used for the combined sample, again examining the academic predictors before examining the cognitive and linguistic predictors, aside from the exclusion of year group as a predictor variable. As in the previous section, the results of these analyses should be interpreted with caution given the reduced sample sizes caused by splitting the participants by year group. Correlations between all predictor variables and performance on the bespoke mathematical tasks measuring arithmetic computation and mathematical WPS are shown in Table 5.14 for each year group separately.

Table 5.14
Correlations between the predictors of interest and mathematical performance; separate year groups

	Arithmetic Computation		Mathematical WPS	
	Year 3	Year 5	Year 3	Year 5
Academic Skills				
Reading Comprehension	.61***	.49**	.66***	.42**
Arithmetic Fluency	.73***	.72***	.72***	.61***
Cognitive & Linguistic Skills				
General Vocabulary	.21	.59***	.43*	.65***
Mathematical Vocabulary	.32	.65***	.42*	.51***
Decoding	.59***	.52***	.63***	.41**
Non-verbal Ability	.04	.52***	-.10	.52***

Note. * indicates $p < .05$, ** indicates $p < .01$, *** indicates $p < .001$

The results of the multiple regression analyses predicting arithmetic computation for the year groups separately are shown in Table 5.15. For the Year 3 children, Model 1 significantly accounted for 70% of the variance in arithmetic computation, $F(3, 26.86) = 24.42$, $p < .001$. Both reading comprehension and arithmetic fluency were found to be significant predictors of arithmetic computation, uniquely accounting for 17% and 5% of the variance in arithmetic computation respectively. Additionally, language group was found to make a significant contribution to arithmetic computation, suggesting that the academic predictors of arithmetic computation in Year 3 children differ between EAL and FLE learners. Model 2 significantly accounted for 50% of the variance in the arithmetic computation scores of the Year 3 group, $F(5, 25.10) = 7.34$, $p < .001$.

Decoding ability was found to be a significant predictor of arithmetic computation, uniquely accounting for 10% of the variance in arithmetic computation, while neither type of vocabulary knowledge nor non-verbal ability was found to be a significant predictor. However, language group did significantly contribute to the model, suggesting that for Year 3 children, the linguistic and cognitive predictors of arithmetic computation differ somewhat between EAL and FLE learners.

For the Year 5 children, Model 1 significantly accounted for 58% of the variance in arithmetic computation, $F(3, 32.33) = 16.91$, $p < .001$. Again, both reading comprehension and arithmetic fluency were identified as significant predictors of Year 5 arithmetic computation, and accounted uniquely for 5% and 37% of the variance in arithmetic computation respectively. Language group was not found to make a significant contribution to the model; this demonstrates that the academic predictors of arithmetic computation in Year 5 children do not differ between EAL and FLE learners. Model 2 significantly accounted for 48% of the variance in Year 5 arithmetic computation, $F(5, 31.05) = 7.97$, $p < .001$. However, no unique cognitive or linguistic predictors of arithmetic computation were identified in the model, and additionally, language group did not make a significant contribution. This suggests that the cognitive and linguistic predictors of Year 5 arithmetic computation do not differ between EAL and FLE learners.

Table 5.15

Multiple regression models predicting arithmetic computation; separate year groups

Predictor	Year 3					Year 5				
	Adjusted R^2	β (*SE*)	*t*	*p*	Unique R^2	Adjusted R^2	β (*SE*)	*t*	*p*	Unique R^2
Model 1 - Academic Predictors	.70					.58				
Language Group		.41 (.12)	3.45	< .001	.11		-.12 (.12)	-0.97	.335	.01
Reading Comprehension		.54 (.13)	4.23	< .001	.17		.25 (12)	2.12	.034	.05
Arithmetic Fluency		.31 (.14)	2.24	.026	.05		.65 (.11)	5.52	< .001	.37
Model 2 - Cognitive & Linguistic Predictors	.50					.48				
Language Group		.59 (.16)	3.61	< .001	.21		-.01 (.13)	-0.05	.960	< .01
General Vocabulary		.37 (.19)	1.95	.052	.06		.17 (.18)	0.97	.331	.01
Mathematical Vocabulary		.11 (.16)	0.70	.484	< .01		.30 (.18)	1.70	.090	.04
Decoding		.36 (.14)	2.57	.010	.10		.25 (.15)	1.62	.107	.04
Non-verbal Ability		.04 (.13)	0.32	.751	< .01		.23 (.14)	1.66	.097	.04

Note. Unique R^2 is represented by squared semi-partial correlations

Table 5.16 presents the results of the multiple regression analyses predicting mathematical WPS for the Year 3 and Year 5 children separately. Model 1 significantly accounted for 64% of the variance in Year 3 mathematical WPS, $F(3, 21.84) = 11.18$, $p < .001$. Reading comprehension and arithmetic fluency were both identified as significant predictors of Year 3 WPS, uniquely accounting for 6% and 21% of the variance respectively. Language group did not significantly contribute to the model, suggesting that the academic predictors of Year 3 WPS are comparable in EAL and FLE children. Model 2 significantly accounted for 46% of the variance in Year 3 WPS, $F(5, 19.85) = 4.36$, $p = .008$. Decoding ability was identified as a significant predictor of Year 3 WPS, uniquely accounting for 22% of the total variance in WPS. Neither type of vocabulary knowledge nor non-verbal ability contributed significantly to the model, nor did language group, suggesting that the cognitive and linguistic predictors of Year 3 mathematical WPS are comparable for EAL and FLE children.

For the Year 5 children, Model 1 was found to significantly account for 38% of the variance in mathematical WPS, $F(3, 22.47) = 5.68$, $p = .005$. Only arithmetic fluency was found to significantly predict Year 5 WPS, uniquely accounting for 26% of the total variance; reading comprehension was not found to be a unique significant predictor. Language group did not make a significant contribution to the model, suggesting that the academic predictors of Year 5 mathematical WPS are the same for EAL and FLE children. Model 2 significantly accounted for 43% of the variance in Year 5 mathematical WPS, $F(5, 27.36) = 5.52$, $p = .001$. General vocabulary knowledge was identified as a significant predictor of Year 5 mathematical WPS, uniquely accounting for 11% of the total variance, however mathematical vocabulary knowledge, decoding ability and non-verbal ability did not significantly contribute to Year 5 WPS. Again, language group did not make a significant contribution to the model, suggesting that the cognitive and linguistic predictors of Year 5 WPS are comparable across the language groups.

Table 5.16

Multiple regression models predicting mathematical WPS; separate year groups

	Year 3					Year 5				
Predictor	Adjusted R^2	β (*SE*)	*t*	*p*	Unique R^2	Adjusted R^2	β (*SE*)	*t*	*p*	Unique R^2
Model 1 - Academic Predictors	.64					.38				
Language Group		-.17 (.17)	-1.01	.320	.02		-.10 (.14)	-0.72	.470	< .01
Reading Comprehension		.32 (.16)	2.11	.037	.06		.22 (.14)	1.49	.135	.04
Arithmetic Fluency		.63 (.16)	3.77	< .001	.21		.54 (.14)	3.74	< .001	.26
Model 2 - Cognitive & Linguistic Predictors	.46					.43				
Language Group		.09 (19)	0.48	.630	< .01		.02 (.14)	0.11	.914	< .01
General Vocabulary		.35 (.21)	1.67	.096	.05		.47 (.22)	2.06	.050	.11
Mathematical Vocabulary		.09 (.18)	0.52	.607	< .01		-.02 (.22)	-0.08	.940	< .01
Decoding		.52 (.15)	3.46	< .001	.22		.15 (.15)	1.00	.318	.02
Non-verbal Ability		-.17 (.14)	-1.16	.247	.03		.27 (.16)	1.78	.076	.05

Note. Unique R^2 is represented by squared semi-partial correlations

5.3.4.4 The Concurrent Correlates of Mathematical Ability by Language Group and Year Group

Given that the sample sizes in the preceding regression analyses were already substantially reduced by comparing the predictors of mathematical ability across certain sub-groups, it was deemed unsuitable to perform further regression analyses splitting the sample by both language group and year group simultaneously. Instead, correlation analyses were carried out for each language group within each year group to give some indication of the relationships between the predictors of interest and performance on the bespoke mathematical tasks for these groups separately. The results of these analyses can be seen in Table 5.17. While the results of these analyses should be interpreted with caution, especially for the EAL groups which are smaller in size, they do largely reflect the results of the preceding regression analyses. Surprisingly, language comprehension skills correlated strongly with EAL arithmetic computation in Year 3, while in Year 5, non-verbal ability alone contributed to EAL arithmetic computation. Regarding mathematical WPS, it seems that in Year 3, vocabulary knowledge is more strongly related to WPS for the EAL group than for the FLE group, while decoding is important for both language groups. By Year 5, it seems that the contribution of decoding ability to WPS has diminished, particularly for the EAL group, while the contribution of vocabulary knowledge to WPS remains strong for both language groups. In addition, while Year 3 WPS seems to be governed solely by linguistic skills, non-verbal ability shows a correlation with WPS by Year 5.

Table 5.17
Correlations between the predictors of interest and mathematical performance, split by year group and language group

	Arithmetic Computation				Mathematical WPS			
	Year 3		Year 5		Year 3		Year 5	
	EAL	FLE	EAL	FLE	EAL	FLE	EAL	FLE
Academic Skills								
Reading Comprehension	.71**	.81***	.23	.62***	.54*	.75***	.48	.38
Arithmetic Fluency	.42	.79***	.75**	.74***	.64**	.86***	.62*	.62***
Cognitive & Linguistic Skills								
General Vocabulary	.63**	.60**	.35	.73***	.74**	.40	.56*	.70***
Mathematical Vocabulary	.54*	.57*	.39	.75***	.41	.58*	.44	.52**
Decoding	.29	.68**	.37	.64***	.52*	.71***	.11	.58**
Non-verbal Ability	-.27	.28	.72**	.41*	-.24	-.02	.57*	.49**

Note. * indicates $p < .05$, ** indicates $p < .01$, *** indicates $p < .001$

5.3.4.5 Summary

In summary, the predictors of mathematical ability seem to be comparable between the EAL and FLE children, though within this, the contribution of comprehension skills to mathematical WPS seems to be stronger for the EAL children. In both language groups, reading comprehension and arithmetic fluency contributed uniquely to arithmetic computation, and arithmetic fluency was a stronger predictor. The unique cognitive and linguistic predictors of arithmetic computation differed somewhat between the language groups; while both language comprehension and decoding skills uniquely predicted arithmetic computation in the FLE group, no significant unique predictors were identified for the EAL group. On further inspection of the correlations between the variables of interest and arithmetic computation, it seems that while language comprehension skills relate to arithmetic computation for the Year 3 EAL children, non-verbal ability is the strongest correlate of arithmetic computation for the Year 5 EAL children. Regarding mathematical WPS, both reading comprehension and arithmetic fluency made a significant unique contribution to mathematical WPS for both language groups. While arithmetic fluency was consistently a stronger predictor overall, reading comprehension was a stronger predictor of WPS for the EAL children than for the FLE children. General vocabulary knowledge and decoding ability were identified as the overall unique cognitive and linguistic predictors of WPS. Vocabulary knowledge was a stronger predictor of WPS for the EAL children than for the FLE children, rendering the contribution of decoding skills non-significant for the EAL children.

Regarding the effect of year group on the predictors of mathematical ability, a general trend suggests that decoding skills become less predictive of mathematical ability between Year 3 and Year 5, particularly in the case of mathematical WPS. Decoding ability was found to uniquely predict arithmetic computation in the Year 3 group but not in the Year 5 group, and while reading comprehension and arithmetic fluency were unique academic predictors of arithmetic computation in both Year 3 and Year 5, the strongest predictor was reading comprehension in Year 3 but arithmetic fluency in Year 5. Similarly, the sole unique cognitive or linguistic predictor of WPS in the Year 3 children was decoding ability, while it was general vocabulary knowledge for the Year 5 children. Accordingly, while both reading comprehension and arithmetic fluency were unique academic predictors of WPS in Year 3, only arithmetic fluency was a unique predictor in Year 5.

5.4 Discussion

This chapter focused on the mathematical abilities of EAL and FLE children in KS2, aiming to compare the performance of the two language groups on both arithmetic and WPS tasks, and to examine the concurrent predictors of arithmetic computation and mathematical WPS for each language group. Regarding the group differences in mathematical performance, it was hypothesised that the EAL children would score significantly lower on the mathematical WPS task but perform at the same level as the FLE children on both measures of arithmetic ability. In addition, it was hypothesised that the difference in scores on the two bespoke mathematical tasks, and thus the effect of contextualising calculations into mathematical word problems, would be greater for the EAL children than for the FLE children. Finally, any significant group differences between the language groups were expected to be larger for the Year 3 children than for the Year 5 children. Regarding the concurrent predictors of mathematical ability, it was hypothesised that the predictors of both arithmetic computation and mathematical WPS would be largely comparable between the

EAL and FLE children. Arithmetic fluency and decoding ability were hypothesised to predict arithmetic computation in both language groups. The predictors of WPS were hypothesised to be reading comprehension, arithmetic ability, general vocabulary knowledge, mathematical vocabulary knowledge, decoding ability and non-verbal ability. In addition, it was predicted that the contribution of comprehension skills to WPS would be stronger for the EAL children. Finally, the concurrent predictors of both arithmetic computation and WPS were predicted to be comparable between the Year 3 and Year 5 children. The results detailed in Section 5.3 somewhat reflect these predictions. The current section will summarise this chapter's findings, applying each finding to the hypotheses as well as the relevant previous research from the literature. In addition, the educational implications of the results will be discussed.

The results of the MANCOVA comparing the mathematical performance of the EAL and FLE children within the combined sample are partially in line with the hypotheses. That is, no significant difference between the EAL and FLE children was found for arithmetic ability or for mathematical WPS. The comparable arithmetic performance of the language groups across the combined sample was hypothesised, given the absence of verbal language in either arithmetic task, and is in line with previous research showing no significant difference in arithmetic ability between language-minority and monolingual children (e.g., Abedi, 2002; Trakulphadetkrai et al., 2017; Xu et al., 2021).

The non-significant overall difference between the language groups in terms of WPS ability was unexpected, given the hypothesis that the EAL group would score significantly lower than the FLE children on the WPS task and the existing research comparing WPS ability between language-minority and monolingual children (e.g., Abedi & Lord, 2001; Trakulphadetkrai et al., 2017; Xu et al., 2021), which has typically found a language-minority disadvantage in WPS. It is possible that this result accurately reflects the WPS abilities of EAL and FLE children of Year 3 and Year 5 age in English primary schools, given the relatively small gap in mathematical achievement observed in national performance data and its diminution over time (Strand et al., 2015). The reported national achievement gap, however, represents differences in overall mathematical achievement rather than mathematical WPS in particular. Research carried out in England with Year 5 children has found EAL children to show weaker WPS skills than their FLE peers (Trakulphadetkrai et al., 2017); taking into consideration this result as well as others from the literature, it seems that the non-significant difference found in the current study might not be an accurate representation of the WPS abilities of EAL and FLE children in England. Instead, methodological issues might have influenced the results regarding the WPS task. Firstly, due to the combination of the sample for the initial analyses and the fact that the bespoke WPS tasks were designed as two different sets of 15 items for the two year groups, 15 points were added to the scores of all Year 5 children to allow meaningful comparison with the Year 3 scores. However, it is not necessarily the case that all Year 5 children, particularly those in the EAL group, would have scored 15 points on the Year 3 task; comprehension difficulties might have impeded performance despite the simpler calculations required and thus caused a reduction in scores. In addition, all participants were given a maximum time limit of 15 minutes to complete the WPS tasks in order to keep all testing sessions to schedule; this might also have resulted in misrepresentation of some participants' WPS ability. The use of a single standardised WPS measure which can be administered to a range of year groups and is not limited by time constraints is recommended for future research to ensure WPS is measured reliably. Secondly, although there was no statistical difference in the SES distribution between the EAL and FLE groups, as evidenced in Section 4.2.1, a greater number of children were eligible for FSM in the FLE group than in the EAL group; it is possible that this resulted in an underestimation of the FLE group mean for WPS given that children of lower SES have widely been found to struggle in both reading and mathematics (e.g., Perry & McConney, 2010). It is therefore possible that a sample with a more equal distribution of FSM eligibility between the EAL and FLE groups might have found a significant difference in WPS between the language groups. Finally, the current study did find the FLE children to score higher, on average, in WPS than the EAL group, While the difference between the groups was not nearing significance, a greater sample size might have revealed a significant difference between the groups.

While no significant differences in mathematical performance between EAL and FLE children were found for the combined sample, a significant effect of year group was found. Accordingly, further analyses were carried out which compared the mathematical performance of the EAL and FLE children within each year group separately; it should be remembered that the results of these analyses should be interpreted with caution given the small sample sizes. While these analyses found no significant difference in WPS ability between the language groups in either year group and reflected the results from the combined sample for the Year 5 group, the Year 3 EAL children were found to significantly outperform the Year 3 FLE group on the arithmetic composite. This result is surprising in light of the evidence from the literature showing no significant difference in arithmetic ability between language-minority and monolingual children (e.g., Abedi, 2002; Trakulphadetkrai et al., 2017; Xu et al., 2021). However, it is notable that the Year 3 EAL children performed higher, on average, than their Year 3 FLE peers on the decoding composite as well as on the measure of working memory used in the current study, although these differences were not statistically significant; both decoding ability and working memory have been identified as key predictors of arithmetic computation (e.g., Fuchs et al., 2006, 2008) and thus might have boosted the arithmetic performance of the Year 3 EAL children relative to that of their FLE peers. In fact, there is evidence to suggest that for children with approximately equal proficiency in two languages, bilingualism is positively associated with skills which are important to arithmetic competence such as working memory and attentional control (e.g., Adesope, Lavin, Thompson & Ungerleider, 2010); it is possible that the arithmetic performance of the Year 3 EAL children in the current study benefitted accordingly.

Within the Year 3 group, the EAL children also showed a significantly greater difference in scores between the bespoke arithmetic and mathematical WPS tasks, as hypothesised. While there is no existing literature which has compared the performance of EAL and FLE children on parallel tasks such as the ones used in the current study, this result accords with previous literature suggesting that contextualisation of arithmetic problems into mathematical word problems causes more difficulty for EAL children than for FLE children (e.g., Martiniello, 2008, 2009). While this result might partially be explained by the strong arithmetic scores exhibited by the Year 3 EAL group, it does demonstrate that even for EAL children with strong arithmetic skills, presenting mathematical problems through verbal language results poses a particular problem and results in a greater reduction in performance than for FLE children. Consequently, it seems likely that the mathematical ability of EAL children might be misrepresented by tests including mathematical word problems, due to the influence of language skills such as vocabulary knowledge or reading comprehension. Schools should ensure that their EAL children are well prepared for tests of mathematical achievement which include a strong language component, focusing not only on supporting mathematical ability but also on familiarising their EAL students with the vocabulary and patterns of language typically used in mathematical word problems in order to support the successful formation of a problem model when solving word problems. Schools might also consider allowing accommodations for EAL children when completing language-heavy mathematics tests; accommodations which have been shown to be effective in allowing EAL children to perform to the best of their ability in such tests include providing bilingual glossaries and simplifying the language content of the questions in the test for the EAL children (e.g. Abedi & Lord, 2001; Kieffer et al., 2009).

An additional hypothesis made in Section 5.1.1 stated that the achievement gap in mathematical WPS between EAL and FLE children would diminish between Year 3 and Year 5, in line with national data which shows the mathematical achievement gap to narrow with age (e.g., Strand et al., 2015). While no significant difference in WPS was found between the language groups in Year 3 nor in Year 5, the group means show that the EAL children marginally outperformed the FLE children in WPS ability in Year 3 while the FLE children outperformed the EAL children in Year 5, suggesting a widening of the achievement gap. Given the reduced sample sizes and the strong arithmetic ability of the Year 3 EAL children in comparison to the Year 3 FLE children, it is unclear whether this finding reflects the pattern of mathematical ability in the wider population. Furthermore, the effect of contextualising arithmetic problems into mathematical word problems on the WPS performance of EAL does seem to diminish with age, given that the difference between scores on the bespoke tasks was non-significant in the Year 5 group. Given these mixed results, it is difficult to draw any conclusions regarding the effect of age on the mathematical abilities of EAL and FLE children; further research should seek to clarify this.

Turning now to the concurrent predictors of mathematical ability in EAL and FLE children, the results from the combined analyses showed that overall, the predictors of WPS and, to some extent, arithmetic computation are comparable for EAL and FLE children given the non-significant effects of language group in both models of WPS and the academic model of arithmetic computation. This is in line with the hypotheses laid out in Section 5.1.1 and also with the limited relevant literature, which has demonstrated the predictors of both arithmetic ability and WPS ability to be comparable between language-minority and monolingual children (Foster et al., 2018; Xu et al., 2021). Both reading comprehension and arithmetic ability were found to be unique academic predictors of mathematical WPS, as expected; this accords with previous research into the predictors of WPS (e.g., Bjork & Bowyer-Crane, 2013; Fuchs et al., 2018; Lin, 2021) and the dual representation model of mathematical WPS (Kintsch & Greeno, 1985) which states that both text comprehension skills and arithmetic competence are together required for successful WPS. It should be noted, however, that such studies typically investigate the role of arithmetic computation in WPS rather than arithmetic fluency. It was not possible to investigate the role of arithmetic computation in WPS in the current study given the parallel nature of the tasks, and thus arithmetic fluency was used as a proxy; while these skills are highly related, they are not equivalent and thus the current study would have benefitted from employing another measure of arithmetic computation which was unrelated in content to the WPS task. Future research should focus on the contribution of arithmetic computation alongside reading comprehension to mathematical WPS in accordance with the literature.

Of the cognitive or linguistic skills hypothesised to uniquely predict mathematical WPS, only general vocabulary knowledge and decoding ability emerged as unique predictors for the combined sample, while mathematical vocabulary and non-verbal ability did not. The finding that general vocabulary knowledge uniquely predicted WPS accords with a multitude of previous research (e.g., Fuchs et al., 2008, 2010; Lin, 2021; Wang et al., 2016) into the predictors of WPS; this is not surprising given the prominent role of verbal language in mathematical word problems. Evidence from the literature also supports the role of decoding ability in mathematical WPS, particularly when the role of arithmetic ability is not concurrently considered (e.g., Foster et al., 2015; Fuchs et al., 2006); this was also to be expected given the role of decoding ability in both reading comprehension and arithmetic ability, both of which have been shown to strongly predict WPS.

The fact that mathematical vocabulary knowledge did not predict WPS above the effects of general vocabulary knowledge in the combined sample, nor indeed in either language group separately, is surprising, given that previous research, although scarce, has typically shown this to be the case (e.g., Fuchs et al., 2015; Peng & Lin, 2019; Xu et al., 2021). There is, however, some evidence to support this finding in the literature; Xu and colleagues found that mathematical vocabulary knowledge did not account for additional variance in WPS over the contribution of receptive vocabulary knowledge in language-minority children specifically. This was also the case in the current study, perhaps because the mathematical vocabulary knowledge of the EAL children was itself impeded by their lower general vocabulary knowledge. Regarding the non-significant contribution of mathematical vocabulary knowledge to WPS in FLE children and indeed in the combined sample, it is possible that the bespoke measures used did not accurately measure mathematical vocabulary knowledge due to their merely satisfactory levels of internal reliability (α

= .64 for the Year 3 task; α = .74 for the Year 5 task). As discussed in Section 4.4, the creation of a rigorously validated, standardised measure of mathematical vocabulary for use in future research would allow its contribution to WPS to be assessed more reliably.

The finding that non-verbal ability did not contribute uniquely to WPS in the combined sample nor indeed in either language group is somewhat surprising given the unique link typically observed in the literature in monolingual children (e.g., Andersson, 2007; Foster et al., 2015). Previous results are more mixed for language-minority children, with non-verbal ability often making no unique contribution to WPS beyond the contributions of mathematical or linguistic skills (e.g., Kempert et al., 2011), perhaps due to the elevated contribution of language comprehension to WPS in language-minority children. Given the presence of EAL children in the combined sample and the reduction in sample size when splitting the sample by language group, it is possible that a unique relationship between non-verbal ability and WPS in FLE children would emerge in future research with larger samples. Future research should also examine the individual role of working memory in mathematical WPS given the link commonly established in the literature (e.g., Lin, 2021; Swanson & Beebe-Frankenberger, 2004; Xu et al., 2021); this was not possible in the current study due to its inclusion in the decoding composite and to the need to reduce the number of variables entered into each model to maximise statistical power.

As with mathematical WPS, both arithmetic fluency and reading comprehension were found to be unique predictors of arithmetic computation across the combined sample. While it was hypothesised that, of the academic predictors, arithmetic fluency alone would predict arithmetic computation given clear evidence from the literature (e.g., Fuchs et al., 2006), it is not surprising that reading comprehension accounted for additional variance given the prominent role of phonological decoding skills in both reading comprehension (e.g., Hoover & Gough, 1990) and arithmetic computation (e.g., Hecht et al., 2001) and the absence of any cognitive or linguistic predictors in the model. This explanation is supported by the fact that for the EAL group alone, reading comprehension was not found to predict arithmetic computation, given the earlier finding from the current study showing that the reading comprehension skills of EAL children are more strongly governed by language comprehension skills than by decoding skills. Notwithstanding, arithmetic fluency was found to be the strongest academic predictor of arithmetic computation across whole the sample, in line with expectations.

The unique cognitive and linguistic predictors of arithmetic computation across the combined sample were found to be decoding ability and mathematical vocabulary. Decoding ability was expected to be the sole cognitive or linguistic predictor, and while it was not found to be the only unique predictor, it was nevertheless the stronger of the two. This accords with evidence from the literature which suggests that phonological skills, which are key to decoding ability, are essential to arithmetic computation (e.g., Hecht et al., 2001; Yang & McBride, 2020). The unique role of mathematical vocabulary knowledge found in the current study is surprising, given that previous research has typically found mathematical vocabulary knowledge to contribute to mathematical WPS but not to arithmetic computation (e.g., Lin, 2021; Powell et al., 2017) and given the clear lack of verbal content in arithmetic computation tasks. It is possible that, within this model, mathematical vocabulary acted as a proxy for general mathematical competence given the lack of such a predictor in the model. Indeed, mathematical vocabulary knowledge is more closely linked to the academic experience than general vocabulary knowledge is (Riccomini et al., 2015). It should be noted that the combination of cognitive and linguistic predictors examined in the current study does not fully reflect the key predictors of arithmetic computation established in the literature, which are phonological skills, processing speed, attention and working memory (e.g., Fuchs et al., 2006, 2008); assessing skills such as processing speed and attention was beyond the scope of the study given the focus on language and mathematical WPS, while entering phonological skills and working memory as individual predictors was not viable due to the need to maximise statistical power. While the decoding composite used does somewhat encompass several of these skills, it is possible that the inclusion of more suitable predictors might have rendered the contribution of mathematical vocabulary non-significant. Nevertheless, it is encouraging that an educational focus on mathematical vocabulary knowledge might contribute to children's general arithmetic competence as well as to their mathematical WPS ability. The fact that neither general vocabulary knowledge nor non-verbal ability uniquely contributed to arithmetic computation is in line with both the hypotheses of the current study and evidence from the literature (e.g., Chow & Ekholm, 2019; Fuchs et al., 2008; Purpura et al., 2011).

Overall, the unique predictors of arithmetic computation and mathematical WPS seem to be comparable between EAL and FLE children and are largely as expected based on evidence from the literature; while arithmetic fluency and decoding skills seem to be essential for both arithmetic computation and mathematical WPS, general language comprehension skills were shown to be uniquely predictive of mathematical WPS only, ostensibly due to the verbal content of mathematical word problems and the resulting demands on text comprehension.

While the unique predictors of mathematical ability seem to be comparable for EAL and FLE children on the whole, some interesting differences were found when examining the predictors for the language groups separately. Firstly, as hypothesised, the contribution of comprehension skills to mathematical WPS seems to be somewhat stronger for the EAL children than for the FLE children. This is evidenced in the fact that general vocabulary knowledge made a substantially stronger unique contribution to WPS in the EAL group ($\beta = .53$, unique $R^2 = .07$) than in the FLE group ($\beta = .24$, unique $R^2 = .03$), in fact rendering the contribution of decoding skills to WPS in the EAL group non-significant. In addition, reading comprehension made a marginally greater unique contribution to WPS in the EAL group than in the FLE group. In conjunction with the fact that the EAL children in the current study were found to have weaker language comprehension skills than the FLE children, the elevated role of language comprehension skills in mathematical WPS for the EAL children suggests that EAL children are at risk of a significant mathematical disadvantage in mathematical WPS, which is a large part of mathematical assessment within the English national curriculum. While this was not evidenced in the current study, given that the EAL children did not perform significantly lower than their FLE peers on the bespoke measure of WPS used, the Year 3 EAL children did face a greater reduction in scores from the arithmetic computation task to the WPS task, and greater differences in WPS ability may have been found by using a standardised measure of mathematical WPS in conjunction with a larger sample.

Interestingly, the cognitive and linguistic predictors of arithmetic computation were found to differ significantly between the EAL and FLE children. In fact, while decoding ability and both types of vocabulary knowledge were found to uniquely predict FLE arithmetic computation, none of the four predictor variables entered into the model made a unique significant contribution for the EAL group. Given that the statistical power of the regression analyses carried out for the language groups separately was substantially reduced, this result should be interpreted with caution, particularly given that the EAL group was smaller than the FLE group. In addition, although there was no single unique predictor in the EAL group, it should be noted that together the four predictors did significantly predict arithmetic computation, accounting for 79% of the variance. Given that this was the case for both language groups, and given also that key predictors of arithmetic computation such as processing speed and attention were not accounted for, this difference between the language groups is not entirely meaningful.

Comparing the unique predictors of arithmetic computation and mathematical WPS within each language group reveals that while the unique academic, cognitive and linguistic predictors of arithmetic computation and WPS are remarkably similar for the FLE group, both reading comprehension and general vocabulary knowledge are unique predictors of mathematical WPS only for the EAL learners. This accords with findings from the literature which show that the comprehension weaknesses faced by EAL learners lead to difficulties with mathematical WPS but not with arithmetic computation in comparison to their FLE peers (e.g., Trakulphadetkrai et al., 2017), reinforcing that the mathematical disadvantage faced by EAL children is specific to language-based tasks such as mathematical WPS tasks.

Finally, exploratory analyses were carried out for the Year 3 and Year 5 children separately in order to examine the predictors of mathematical ability over time. It should be remembered that these results do not reflect the longitudinal pattern of predictors over time in one group of children but rather simply provide a comparison between two different groups of children at different stages in their education. Overall, the results of these exploratory analyses suggest that the predictors of both arithmetic computation and mathematical WPS are somewhat comparable between Year 3 and Year 5; while this contrasts with the findings of Lin (2021), it is not surprising given the relative closeness in age of the year groups. Although the predictors were largely comparable, it seems that the unique contribution of decoding skills to both mathematical tasks declines from Year 3 to Year 5. In the case of mathematical WPS, decoding was the only unique predictor of WPS in Year 3 while general vocabulary knowledge was the only unique predictor in Year 5. This result seems to reflect the decline of the contribution of decoding skills to reading comprehension over time found in the current study and also in the literature (e.g., Ouellette & Beers, 2010; Tilstra et al., 2009); it seems that as children develop full competence in decoding, their decoding skills no longer act as a limiting factor to their mathematical WPS ability, while language comprehension continues to exert a strong influence. Unfortunately, given the small sample size in the current study, it was not possible to examine the predictors of mathematical ability separately for each year group within each language group to search for any nuances in the effect of age caused by language group status; future research with a larger sample should seek to do this.

Overall, the results presented in this chapter are somewhat in line with those found in the literature. While no significant differences in mathematical WPS ability were found between the EAL and FLE children in the current study, further analyses revealed that contextualising arithmetic problems into mathematical word problems caused a significantly greater reduction in scores for the Year 3 EAL group than for the Year 3 FLE group, providing evidence that the strong arithmetic abilities of EAL children can be misrepresented by assessments involving language-heavy items such as mathematical word problems, particularly in younger age groups. Analyses also demonstrated that, while the predictors of mathematical ability are largely comparable for EAL and FLE children, both reading comprehension and general vocabulary knowledge play a greater role in the mathematical WPS abilities of EAL children than those of FLE children. While comprehension skills were consistently predictive of mathematical ability, the contribution of decoding skills seemed to decline between Year 3 and Year 5; analysis of the longitudinal predictors of mathematical ability will be performed in Chapter 6. The results presented in this chapter suggest that EAL children should be given additional support in preparing for mathematical assessments involving language-heavy items, focusing on supporting the formation of problem models through accurate comprehension of the text. The results of this chapter also suggest that targeting language skills such as general vocabulary knowledge and reading comprehension is likely to boost EAL performance in mathematics overall; as recommended in Section 4.4, 1-1 or small group sessions with EAL children focusing on such skills would help to achieve this. However, targeting mathematical vocabulary knowledge in particular is not recommended, given the lack of a significant predictive relationship between mathematical vocabulary knowledge and mathematical WPS in the current study. Furthermore, the current chapter has confirmed that EAL children do not need additional support in arithmetic despite any mathematical achievement gap found between EAL and FLE children. In addition, the importance of language comprehension to the WPS abilities of EAL children again emphasises the need to assess the PiE levels of EAL children in English schools in order to identify those most at risk for difficulties in mathematical assessment; the heterogeneity of the EAL population in England is likely to mask areas of weakness for EAL children with low levels of PiE when comparing the groups in a binary way both in research and in practice. In light of the methodological limitations of the current study, further research should be carried out with a larger sample and the inclusion of a standardised measure of mathematical WPS. Future research should also seek to clarify the role of mathematical vocabulary knowledge in the mathematical achievement of EAL and FLE children. Notwithstanding, the current study is one of the first in the literature to directly investigate the effect of contextualising arithmetic problems into mathematical word problems for EAL children and FLE children using parallel mathematical tasks, and despite its limitations, the current study provides further evidence that comprehension skills are vital to mathematical WPS in EAL children and should be targeted in order to ensure that the mathematical skills of EAL children are not misrepresented in mathematical achievement tests.

6 Linguistic and Mathematical Development: Longitudinal Analysis

6.1 Introduction

This chapter aims to investigate and compare the development of linguistic and mathematical abilities in EAL and FLE children over time, as well as the longitudinal predictors of reading comprehension and mathematical abilities in both language groups. Specifically, this chapter investigates these aims with KS2 children in English primary schools, following one group of Year 3 children into Year 4 and a separate group of Year 5 children into Year 6. While the effect of time is somewhat reflected in the analyses performed in Chapters 4 and 5 given the two different year groups within the T1 sample, the analyses carried out in this chapter are longitudinal and thus enable the development of skills over time within groups of participants to be observed. Specifically, this chapter will compare the developmental trajectories of both linguistic skills and mathematical performance between EAL and FLE children between Year 3 and Year 6. In addition, the growth in linguistic skills and mathematical performance between T1 and T2 will be compared between the EAL and FLE children. Finally, the longitudinal predictors of reading comprehension and mathematical performance will be examined for the EAL and FLE children. Furthermore, given the school closures caused by the COVID-19 pandemic which occurred between T1 and T2, the home-learning experiences of the participants and their effects on the development of linguistic and mathematical skills in both language groups will be considered.

Focusing first on the linguistic skills of EAL and FLE children, there is an abundance of evidence from the literature that EAL children show significantly weaker reading comprehension and language comprehension skills than their FLE peers, but have comparable levels of decoding skills (e.g., Hutchinson et al., 2003; Melby-Lervåg & Lervåg, 2014). The trajectories and rates of development in linguistic skills in language-minority and monolingual children have also been well-researched in the literature. UK-based longitudinal studies assessing reading comprehension have typically found EAL children to have lower reading comprehension scores than their FLE peers at all time points (e.g., Burgoyne et al., 2011; Hutchinson et al., 2003); for example, Hutchinson and colleagues found an EAL disadvantage across Years 2, 3 and 4, with the reading comprehension skills of the EAL children lagging approximately 1 year behind those of the FLE children. International studies have typically shown similar results (e.g., Lervåg & Aukrust, 2010; Verhoeven & van Leeuwe, 2012); for example, Verhoeven and van Leeuwe found a language-minority reading comprehension disadvantage in Grades 2, 4 and 6 in a sample from the Netherlands. Some studies have reported a similar pattern but only for EAL children with low levels of PiE (e.g., Halle, Hair, Wandner, McNamara & Chien, 2012; Kieffer, 2008); in these studies, EAL children with high levels of PiE had comparable reading comprehension skills to their FLE peers throughout. While the majority of research has found a consistent gap in reading comprehension between EAL and FLE children over time, findings regarding the rate of growth in the two language groups vary. That is, some studies have found the gap in reading comprehension ability between the language groups to widen over time, due to the language-minority children making slower progress than the monolingual children. For example, this effect has been observed between Year 3 and Year 4 in a UK-based study (Burgoyne et al., 2011), between Grade 2 and Grade 3 in a study from Norway (Lervåg & Aukrust, 2010) and between kindergarten and Grade 5 in a study carried out in the USA (Kieffer, 2008). Conversely, some studies have found language-minority children to make quicker progress in reading comprehension than their monolingual peers and thus reported a narrowing of the gap between the language groups. This effect was observed between kindergarten and Grade 8 in a sample from the USA (Halle et al., 2012) and between Grades 7 and 9 in a sample from the Netherlands (Trapman, van Gelderen, van Schooten & Hulstijn, 2017). In fact, the latter study found that the gap in reading comprehension between the language groups was no longer significant by Grade 9. Overall, the existing research suggests that EAL children, particularly those with relatively weak levels of PiE, consistently show weaker reading comprehension skills than their FLE peers over time. Evidence regarding the rate of growth in EAL children relative to FLE children is mixed, however there seems to be a slight tendency for the gap in reading comprehension skills to widen over time, particularly during the primary school years.

Similarly, the literature suggests that EAL or language-minority children consistently show weaker language comprehension skills, such as listening comprehension and vocabulary knowledge, in comparison to their monolingual peers over time, both in the UK (e.g., Burgoyne et al., 2011; Dixon et al., 2022; Hutchinson et al., 2003; Mahon & Crutchley, 2006) and elsewhere (e.g., Droop & Verhoeven, 2003; Geva & Farnia, 2012; Karlsen, Lyster & Lervåg, 2017; Simos, Sideridis, Mouzaki, Chatzidaki & Tzevelekou, 2014; Verhoeven & van Leeuwe, 2012). For example, Geva and Farnia found a consistent EAL disadvantage in both vocabulary knowledge and listening comprehension in Canadian children between Grades 2 and 5. While there is limited evidence showing that EAL children have weaker mathematical vocabulary skills than their FLE peers (Kazima, 2007; Powell et al., 2020), this achievement gap has not been studied longitudinally. As with reading comprehension, results from the literature comparing the rate of growth in language comprehension skills between language-minority and monolingual children are mixed. Some studies have found the gap in vocabulary knowledge to narrow over time, due to a faster rate of growth in language-minority children; this pattern was observed between Grades 1 and 3 in a sample from Greece (Simos et al., 2014), in Norwegian children between kindergarten and Grade 1 (Karlsen et al., 2017) and between Reception and Year 5 in a UK-based study (Mahon & Crutchley, 2006), although this latter study was not strictly longitudinal and instead measured six different groups of children of increasing ages. Conversely, some studies from the UK have shown mixed results regarding the language comprehension skills of EAL and FLE children over time; Hutchinson and colleagues found the EAL disadvantage to narrow in receptive vocabulary but widen in expressive vocabulary and listening comprehension, while Burgoyne and colleagues (2011) found the EAL disadvantage to widen in receptive vocabulary but narrow in expressive vocabulary. A study aggregating data from several published and unpublished studies carried out in the UK found the EAL disadvantage in receptive vocabulary knowledge to narrow over time, while no convergence in expressive vocabulary knowledge was evident (Dixon et al., 2022). No research was found comparing the development of mathematical vocabulary over time between EAL and FLE children. In summary, EAL children tend to show consistently weaker language comprehension skills than their FLE peers over time, but evidence regarding the rate of growth in EAL and FLE children is somewhat mixed. Interestingly, there is evidence that the size of the lag in vocabulary knowledge between EAL and FLE is related to the amount of English spoken in the home by the EAL children (Ribot, Hoff & Burridge, 2018); perhaps the mixed results observed are a result of this. Research regarding the decoding skills of language-minority and monolingual children over time typically suggests that the language groups have consistently comparable decoding skills which follow a similar developmental trajectory (e.g., Burgoyne et al., 2011; Lesaux et al., 2007), with some studies reporting an emerging language-minority advantage over time (e.g., Droop & Verhoeven, 2003; Geva & Farnia, 2012).

There is a wealth of evidence from the literature suggesting that the key concurrent predictors of reading comprehension in both language-minority and monolingual children are decoding and language comprehension (e.g., Babayiğit, 2014, 2015; Gottardo & Mueller, 2009; Verhoeven & van Leeuwe, 2012); that is, the SVR (Gough & Tunmer, 1986) seems to be valid for both language groups. Some studies have reported that language comprehension skills are more predictive of concurrent reading comprehension for language-minority children than for monolingual children (e.g., Babayiğit, 2014; Droop & Verhoeven, 2003; Verhoeven, 2000), although others have found no difference in the strength of language comprehension skills as predictors of reading comprehension between the two groups (e.g., Babayiğit, 2015; Lesaux et al., 2006). Longitudinal studies investigating the predictors of reading comprehension in monolingual children over a number of years have typically found both decoding and language comprehension to predict later reading comprehension scores, and have additionally reported that the predictive power of decoding declines with age, while the predictive power of language comprehension remains strong or even increases over time, ostensibly due to children reaching full mastery of decoding ability (e.g., Adlof et al., 2006; Tilstra et al., 2009). Research investigating the longitudinal predictors of reading comprehension in both language-minority and monolingual children has typically echoed these findings, primarily demonstrating that decoding and language comprehension skills predict later reading comprehension ability in both language groups across a range of primary school grades (e.g., Burgoyne et al., 2011; Droop & Verhoeven, 2003; Geva & Farnia, 2012; Verhoeven & van Leeuwe, 2012). Such studies have also commonly found language comprehension skills to be stronger longitudinal predictors of reading comprehension for EAL or other language-minority children (Burgoyne et al., 2011; Droop & Verhoeven, 2003; Geva & Farnia, 2012), though Verhoeven and van Leeuwe did not find a difference in the strength of language comprehension as a predictor between the groups. Finally, there is evidence that the contribution of decoding skills to reading comprehension declines over time in language-minority children as well as in monolingual children (Droop & Verhoeven, 2003; Verhoeven & van Leeuwe, 2012). Overall, it seems that the longitudinal predictors of reading comprehension are likely to be comparable between EAL and FLE children, and to follow the same patterns as typically observed when investigating the concurrent predictors of reading comprehension.

Turning now to the mathematical performance of EAL or language-minority and monolingual children, the literature suggests that language-minority children typically perform significantly lower than their monolingual peers on tests of mathematical WPS ability, but not on tests of arithmetic ability (e.g., Trakulphadetkrai et al., 2017; Xu et al., 2021). Very few studies exist in the literature which compare the mathematical abilities of language-minority and monolingual children longitudinally over a given period of time. The existing studies typically suggest that language-minority children consistently underperform in mathematics, particularly in mathematical WPS, in relation to their monolingual peers, and make slower progress over time, resulting in a widening achievement gap (Chang et al., 2009; Halle et al., 2012; Mädamürk, Kikas & Palu, 2016). For example, both Chang and colleagues and Halle and colleagues found EAL children in the USA to underperform on a general mathematical achievement test in kindergarten and to make slower progress in mathematics over a number of years than their FLE peers. It should be noted, however, that Halle and colleagues only noticed this trajectory for EAL children with low levels of PiE on starting school; those with higher levels of PiE showed very similar mathematical achievement to their FLE peers over time. Mädamürk and colleagues did not include language-minority children in their study of mathematical development in Estonian children between Grades 3 and 5, but instead compared the developmental trajectories of arithmetic ability and WPS ability between children with low verbal ability, who have comparable academic profiles to EAL children, and children with high verbal ability. This study showed the development of arithmetic ability to be comparable between the two groups, while children with low verbal ability showed lower levels of WPS ability in Grade 3 and made slower progress over time, resulting in a widening achievement gap between the two groups. It should be noted that none of these studies were carried out in the UK, and in fact the results of the two studies measuring general mathematical achievement over time are somewhat at odds with national performance data from England which shows a narrowing of the mathematical achievement gap between EAL and FLE children throughout primary school (Strand et al., 2015). While this discrepancy might be explained by the fact that this national data does not account for variation in performance on different mathematical tasks or for EAL PiE levels, further research is warranted which examines the developmental trajectories of mathematical achievement in EAL and FLE children in the UK.

Limited evidence from the literature suggests that the concurrent predictors of both arithmetic computation and mathematical WPS are somewhat comparable for language-minority and monolingual children (Foster et al., 2018; Xu et al., 2021). Specifically, it seems that the key concurrent predictors of arithmetic computation include phonological skills, working memory, attention and processing speed (e.g., Fuchs et al., 2008) while the key concurrent predictors of mathematical WPS include arithmetic computation, language comprehension skills, working memory and non-verbal ability (e.g., Spencer et al., 2020). In addition, there is limited evidence to suggest that language comprehension skills are stronger predictors of WPS ability for language-minority children than for monolingual children (Trakulphadetkrai et al., 2017; Xu et al., 2021), and that within primary school, skills such as language comprehension, non-verbal ability and working memory become more concurrently predictive of mathematical WPS with age (Lin, 2021). Longitudinal research with monolingual children has typically identified the longitudinal predictors of arithmetic computation and mathematical WPS in primary school children to be comparable to the concurrent predictors of the same skills (e.g., Björn et al., 2016; Fuchs et al., 2016; Jögi & Kikas, 2016; Spencer et al., 2020). The same has been found to be true for EAL children (Foster et al., 2018), although evidence is very limited. No research directly comparing the longitudinal predictors of mathematical ability between EAL and FLE children was found in the literature, meaning that a comparison of the strength of language comprehension as a longitudinal predictor of WPS in EAL and FLE children is not in evidence, however it seems likely that the longitudinal predictors of arithmetic computation and WPS are comparable for EAL and FLE children given the similarities between the longitudinal and concurrent research for the language groups separately. The current study aims to investigate this possibility.

While previous research into the longitudinal development of linguistic skills and mathematics in language-minority and monolingual children is a valuable frame of reference for the current study, it is important to consider the unique context of the academic year which elapsed between T1 and T2 of the current study. The severity of the COVID-19 pandemic resulted in sudden nationwide school closures, with only vulnerable children and children of key workers attending school between the 20th of March 2020 and the start of the summer break in July; while some school years did return to school for a short period in June 2020, Year 3 and Year 5 children did not. This resulted in the majority of the participants in the current study being absent from school for almost 6 months, relying solely on home learning provision from their schools. It is therefore likely that the reading and mathematics development of the current sample might follow a somewhat different trajectory to that of samples found in previous research who did not experience such a disruption to their education. Indeed, evidence from recent review papers suggests that overall, COVID-19 school closures negatively affected academic achievement, including in reading and mathematics, across many countries (Hammerstein, König, Dreisörner & Frey, 2021; König & Frey, 2022; Zierer, 2021). For example, Hammerstein and colleagues found that of 11 studies reviewed, seven reported a negative effect on mathematical achievement and five reported a negative effect on reading ability. König and Frey conducted a meta-analysis of the effect of the COVID-19 school closures on academic performance, finding an overall effect of d = -0.18 and commenting that learning losses per week of school closures were in the range of typical weekly summer learning losses. These studies also reported that younger children and children from low SES families were most affected by the school closures. A report investigating the academic performance of Year 2 children from 168 schools across England in autumn 2020 revealed that attainment in both mathematics and reading was significantly lower in autumn 2020 than in a standardised sample from autumn 2017; in both cases, a learning loss equivalent to 2 months was suggested (Rose et al., 2021). Overall, this evidence suggests that the academic performance of the T2 sample might be somewhat lower than typically expected.

Very little research has investigated the effect of the COVID-19 school closures on EAL children in particular. Sugarman and Lazarín (2020) suggested that the negative effect of the school closures might be more pronounced for EAL children, reporting that, across schools in Chicago and Los Angeles, only approximately half of the EAL learners regularly participated in remote learning activities. The authors cited several reasons for this, including lack of digital access, language barriers limiting the capacity of many parents of EAL children to support home learning as well as their communication with schools, and a lack of home learning resources suitable for EAL learners. Prolonged periods with no formal schooling, such as summer breaks, have also been found to disproportionately reduce the English vocabulary skills of EAL learners in comparison to FLE learners (e.g., Lawrence, 2012), ostensibly due to reduced use of English outside of school. It therefore follows that the COVID-19 school closures are likely to have resulted in significant vocabulary losses for EAL children, which in turn might have negatively affected their academic performance given the strong link between EAL PiE and academic achievement (e.g., Strand & Hessel, 2018). Indeed, in a teacher survey carried out in March 2021 by The Bell Foundation (2021), 74% of primary school teachers surveyed reported that they had observed language loss in their EAL pupils in one or more of reading, writing, speaking and listening following the COVID-19 school closures. The PiE level of the children's families was a commonly cited explanation for observed language loss. In addition, approximately one in six teachers who had observed language loss reported that this led to a loss in their EAL students' confidence in speaking in class or with their peers. Overall, although limited, this evidence suggests that the academic performance of EAL children might have been disproportionately affected by the school closures during the COVID-19 pandemic as a result of a loss in vocabulary knowledge; this possibility will be considered when interpreting the results of analyses performed in this chapter. Specifically, it is possible that the EAL children in the current study will show signs of slower progress in vocabulary knowledge, reading comprehension and mathematical WPS over time relative to their FLE peers.

Taken together, the results of the discussed research do not give a clear picture of the developmental trajectories of reading comprehension and its subcomponents nor of mathematical performance in EAL children and how these compare to those of their FLE peers. In particular, research specific to the UK context is limited, particularly in the case of mathematics, and has not examined the development of linguistic or mathematical performance across all KS2 years. This is also true in regard to research investigating the longitudinal predictors of reading comprehension in EAL and FLE children. Furthermore, no previous research was found which compared the longitudinal predictors of mathematical ability across the language groups. In light of the discussed research, therefore, the current chapter aims to compare the developmental trajectories of reading comprehension, its subcomponents and mathematical performance between EAL and FLE children across the course of KS2, and to examine the longitudinal predictors of reading comprehension and mathematical performance in EAL and FLE children. In addition, participants' experiences during the school closures which occurred between T1 and T2 and their potential effect on the academic development of both the EAL and FLE children will be considered.

6.1.1 Research Questions and Hypotheses

This chapter addresses research questions 6 to 9 as laid out in Section 2.5. These are:

6. How do the linguistic abilities of EAL and FLE children change over the course of KS2?
    a. How do the developmental trajectories of reading comprehension and its subcomponents over the course of KS2 compare between EAL and FLE children?
    b. Do the rates of growth in reading comprehension and its subcomponents between Year 3 and Year 4, and between Year 5 and Year 6 differ for EAL and FLE children?
7. What are the longitudinal predictors of reading comprehension in EAL and FLE children across the course of KS2?
8. How does the mathematical performance of EAL and FLE children change over the course of KS2?
    a. How do the developmental trajectories of arithmetic ability and mathematical WPS over the course of KS2 compare between EAL and FLE children?
    b. Do the rates of growth in arithmetic ability and mathematical WPS between Year 3 and Year 4, and between Year 5 and Year 6 differ for EAL and FLE children?
9. What are the longitudinal academic, cognitive and linguistic predictors of arithmetic computation and mathematical WPS in EAL and FLE children across the course of KS2?

Regarding research question 6, it is hypothesised that the EAL children will show consistently lower mean reading comprehension scores and will make slower progress over time than their FLE peers between Year 3 and Year 6. A similar pattern is anticipated for vocabulary knowledge, while the developmental trajectories for decoding ability are expected to be comparable across the language groups. The developmental trajectory of mathematical vocabulary knowledge is expected to be comparable to that of general vocabulary knowledge; however, this prediction is unsupported by evidence given the lack of longitudinal research into the mathematical vocabulary knowledge in EAL and FLE children. Regarding research question 7, it is hypothesised that the unique longitudinal predictors of reading comprehension will be comparable for the EAL and FLE children, and will consist of T1 decoding ability and T1 vocabulary knowledge. In addition, it is predicted that the longitudinal contribution of decoding ability to reading comprehension will decrease over time, and that T1 vocabulary knowledge will contribute more strongly to T2 reading comprehension for the EAL children than for the FLE children.

Regarding research question 8, it is anticipated that the EAL children will show consistently lower mean WPS scores and slower growth over time than the FLE children between Year 3 and Year 6. The developmental trajectories of the EAL and FLE children for arithmetic ability are expected to be comparable. Regarding research question 9, it is hypothesised that the longitudinal predictors of arithmetic computation will be comparable for the EAL and FLE children. Specifically, T1 arithmetic fluency is expected to be the sole longitudinal academic predictor of arithmetic computation, while T1 decoding ability is expected to be the sole longitudinal cognitive or linguistic predictor. The longitudinal predictors of mathematical WPS are also predicted to be comparable for the EAL and FLE children; specifically, both T1 reading comprehension and T1 arithmetic fluency are expected to be longitudinal academic predictors of WPS, while T1 general vocabulary knowledge, T1 mathematical vocabulary knowledge, T1 decoding and T1 non-verbal ability are expected to be longitudinal cognitive or linguistic predictors of WPS.

6.2 Method

6.2.1 Design and Participants

This chapter analyses the data collected at both T1 and T2 for the children who participated in both testing points, according to the design detailed in Section 3.2.1. As such, the sample used in this chapter consists of 42 children (19 EAL, 23 FLE). These children participated in the study in the autumn of 2019 and again in the autumn of 2020 and were recruited from Schools 1, 2 and 3 as specified in Section 3.3.1. The 28 children from Schools 4 and 5 who participated at T1 were not able to participate at T2 due to school closures in January 2021 caused by the COVID-19 pandemic. In addition, a further two children from Schools 1 and 2 were lost to attrition, resulting in a final sample size of 42. Demographic information for the T2 sample is shown in Table 6.1.

Table 6.1
Participant demographics; T2

	Year 4	Year 6	Combined sample
N	19	23	42
% EAL	47.3%	39.1%	42.9%
% FSM	21.1%	17.3%	19%
% Male	52.6%	30.4%	40.5%
Mean age in months (*SD*)	102.32 (3.11)	128.26 (3.24)	116.52 (13.44)

Independent samples *t*-tests conducted on the T2 sample revealed no significant difference in age between the EAL (M = 102.78, SD = 3.07) and FLE children (M = 101.90, SD = 3.25) in Year 4,

$t(17) = -0.60$, $p = .554$, nor between the EAL ($M = 126.89$, $SD = 3.62$) and FLE children ($M = 129.14$, $SD = 2.74$) in Year 6, $t(21) = 1.70$, $p = .104$. Chi square tests revealed no significant differences in gender distribution (Year 4: $\chi^2(1) = 1.35$, $p = .245$; Year 6: $\chi^2(1) = 0.06$, $p = .809$) nor in FSM eligibility (Year 4: $\chi^2(1) = 1.02$, $p = .313$; Year 6: $\chi^2(1) = 0.24$, $p = .624$) between the EAL and FLE children. The EAL children at T2 spoke a total of 10 different L1s; these were Bengali (7 children), Romanian (2), Spanish (2), Urdu (2), Arabic (1), Pashto (1), Portuguese (1), Italian (1), Punjabi (1) and Uzbek (1).

6.2.2 Measures

At T2, a reduced test battery was used, given that phonological and cognitive skills were not required for the planned T2 analyses. The measures which were administered at T2 are shown in Table 6.2. Select additional T1 measures including the composite variables created in Section 4.3.2 as well as non-verbal ability were used when analysing the longitudinal predictors of academic achievement; a full list of measures administered at T1 can be found in Table 3.13. In addition, online questionnaires regarding the home learning experiences of the sample were distributed to all parents at T2, and a simplified version was administered to all participants during their first T2 testing session.

Table 6.2
T2 test battery

Skill	Measure
Mathematical Skills	
Arithmetic Fluency	Addition, Addition with Carry, Subtraction, Subtraction with Carry, Multiplication; TOBANS
Arithmetic Computation	Bespoke task
Mathematical WPS	Bespoke task
Passage Reading	
Reading Comprehension	YARC
Reading Accuracy	YARC
Reading Rate	YARC
Decoding Skills	
Word Reading	DTWRP
Vocabulary	
Receptive Vocabulary	BPVS3
Expressive Vocabulary	Vocabulary; WASI-II
Mathematical Vocabulary	Bespoke task

6.2.3 Procedure

The procedure for both the T1 and T2 sessions followed the procedure described in Section 3.6, using the testing schedules found in Table 3.13. At both time points, the measures were divided between two testing sessions per child, approximately one week apart. At T1, sessions lasted approximately 40 minutes, while sessions at T2 lasted approximately 25 minutes due to the reduced test battery. All sessions were carried out in a quiet place during school hours.

6.3 Results

6.3.1 The Educational Experiences of the T2 Sample during the COVID-19 School Closures

Before the research questions are addressed, this section will summarise the educational experiences of the T2 sample during the initial school closures caused by COVID-19. Questionnaires on the topic were administered to all T2 participants during their first T2 data collection session. In addition, the parents of all T2 children were sent a similar questionnaire, however the response rate was low (33%) and thus only the child questionnaire data was analysed. It is acknowledged that dependence on the child responses alone raises issues surrounding the reliability of the data generated from the child version of the questionnaire, particularly for the younger children.

Of the 42 children in the T2 sample, nine attended school during the school closures due to their parents being classified as key workers. Of these nine children, five attended school throughout the entirety of the school closures, either full-time (3 children) or for 3 days per week (2 children), while the remaining four children attended school for a shorter period towards the end of the summer term only. Of the children who attended school during the school closures, eight were FLE learners while only one was an EAL learner. The majority of the sample reported taking part in home-learning activities set for them by their teachers; only five children reported that they did not, including the three children who attended school full-time throughout the school closures. Typically, the children who participated in home-learning activities reported receiving help with these activities from one or more of their parents or older siblings, although eight children, of which five children were EAL learners, completed the activities independently.

Amongst the children who did not attend school regularly throughout the school closures, wide variation in the frequency of participation in home learning activities was observed. The typical number of days per week on which the children participated in home learning activities ranged from 0 to 5, while the typical number of hours per day dedicated to home learning reported ranged from 0 to 4. While the EAL children were found to participate in home learning activities less frequently than the FLE children on average, no significant difference in the total number of hours per week dedicated to home learning was found between the EAL (M = 5.94, SD = 3.19) and FLE (M = 9.10, SD = 6.78) children, $t(27.94) = 1.86$, $p = .074$. All children reported working on literacy and mathematics for approximately equal amounts of time each week.

The questionnaire administered at T2 also asked children about how often they engaged in reading over the course of the school closures; the answer options were never (1), less often (2), once or twice per week (3), once every two days (4) and every day (5). The majority of participants read often, with 48% of participants reading every day and a further 36% of participants reading every two days. No significant difference in the frequency of reading during the school closures was found between the EAL (M = 4.22, SD = 0.88) and FLE children (M = 4.13, SD = 1.15), $t(40) = -0.30$, $p = .767$.

Finally, the questionnaire asked the T2 participants about their experiences learning literacy and mathematics after school started again in the autumn term of 2020. Participants specified whether they now found learning literacy and mathematics in school much easier (1), a bit easier (2), the same (3), a bit harder (4) or much harder (5) than they had before the school closures. While 54% of the sample reported no change in their experiences of literacy and mathematics learning, 40% reported that they found school slightly more challenging than they had before the school closures. No significant difference in the perception of literacy and mathematics learning following the school closures was found between the EAL (M = 3.33, SD = 0.59) and FLE children (M = 3.38, SD = 0.58), $t(40) = 0.23$, $p = .820$.

Overall, the vast majority of the T2 sample either engaged in home learning activities during the initial COVID-19 school closures or attended school full-time due to their parents being key workers. The amount of home learning participation varied widely within the sample, and while the EAL children did engage with home learning activities to a lesser extent than the FLE children on average, this difference was not statistically significant. In addition, no significant differences between the language groups were found in reading engagement during the school closures nor in perceptions of learning when restarting school in the autumn. Where appropriate, the contributions the variables examined in this section to the academic development of the sample will be investigated within the proceeding sections.

6.3.2 The Development of Linguistic Skills in EAL and FLE Children

This section presents the results of a series of analyses investigating the development of reading comprehension and its subcomponents in EAL and FLE children. Firstly, the developmental trajectories of these skills between Year 3 and Year 6 will be examined using descriptive statistics. Following this, the growth over time for each variable will be compared statistically between the EAL and FLE children. Finally, the longitudinal predictors of reading comprehension will be examined.

6.3.2.1 Correlations between the T2 Variables and the Creation of Composite Variables

In order to examine the relationships between the measures collected at T2, partial correlations, controlling for year group, were calculated for the T2 sample. The results of this analysis are presented in Table 6.3. The strongest correlations were found between reading accuracy, reading rate and word reading, and also between reading comprehension, receptive vocabulary knowledge and expressive vocabulary knowledge, as anticipated. In addition, mathematical vocabulary knowledge was strongly correlated with all variables.

Table 6.3

Partial correlations between the T2 measures, controlling for year group

	1.	2.	3.	4.	5.	6.	7.
1. Reading Accuracy							
2. Reading Rate	.75***						
3. Reading Comprehension	.49**	.50***					
4. Receptive Vocabulary	.59***	.51***	.80***				
5. Expressive Vocabulary	.51***	.56***	.80***	.76***			
6. Mathematical Vocabulary	.68***	.69***	.65***	.69***	.66***		
7. Word Reading	.82***	.80***	.45**	.48**	.47**	.59***	

Note. * indicates $p < .05$, ** indicates $p < .01$, *** indicates $p < .001$

For the purposes of examining the developmental trajectories of reading comprehension and its subcomponents, it was decided that composite variables representing decoding ability and general vocabulary knowledge would be created. The Decoding composite consisted of reading rate, reading accuracy and word reading, while the General Vocabulary composite consisted of receptive vocabulary knowledge and expressive vocabulary knowledge. Given the current study's focus on mathematics and the fact that mathematical vocabulary knowledge correlated approximately equally with all variables, the development of mathematical vocabulary in the two language groups was considered separately and thus mathematical vocabulary knowledge was not included in the general vocabulary composite. These variables were created using the relevant variables for both T1 and T2, to ensure comparison of the same abilities across the two time points, and were calculated by taking the mean across the *z*-scores of the relevant variables.

6.3.2.2 The Developmental Trajectories of Linguistic Skills in EAL and FLE Children

In order to examine the developmental trajectories of reading comprehension and its subcomponents in EAL and FLE children and thus answer research question 6a, descriptive statistics for the linguistic skills measured at both time points were calculated for the language groups separately across each year group, as well as effect sizes (Cohen's *d*) representing the differences between the two language groups. These group differences were tested inferentially, however the results of these analyses should be interpreted with caution given the reduced sample size when considering only the children who participated at both time points. Specifically, the trajectories of reading comprehension, general vocabulary knowledge, mathematical vocabulary knowledge and decoding were examined; the results of this can be found in Table 6.4 and are presented visually in Figures 6.1, 6.2, 6.3 and 6.4. It should be noted that these statistics are not fully longitudinal; while the Year 3 and Year 4 statistics represent the abilities of the same children, the Year 5 and Year 6 statistics represent the abilities of a separate group of children. Nevertheless, these statistics give a useful indication of how the linguistic abilities of EAL and FLE children change over time. Statistical comparisons of the growth rate of linguistic abilities over time will be performed in Section 6.3.2.5.

On average, the EAL children showed lower reading comprehension scores than their FLE peers at all time points; these differences were, however, not statistically significant. Over time, the development of reading comprehension in the two language groups followed a somewhat similar trajectory, although the EAL children made somewhat slower progress on average between Year 3 and Year 4 than their FLE peers. On average, the EAL children also scored consistently lower on the general vocabulary knowledge composite. These gaps in vocabulary knowledge were statistically significant for the Year 3 and Year 6 groups only. The EAL children also made somewhat faster progress than the FLE children between Year 3 and Year 4. In addition, the general vocabulary knowledge of the EAL children decreased between Year 5 and 6, but increased slightly for the FLE children. The mathematical vocabulary knowledge of the EAL children was slightly lower, on average, than that of the FLE children at all time points, although the two language groups followed a similar trajectory and no significant differences between the language groups were found for any year group. A more pronounced difference between the groups was found for the Year 5 group than for the Year 3 group, however this difference narrowed by Year 6. Finally, the EAL children scored higher in decoding, on average, than the FLE children in Years 3 and 4, but slightly lower than the FLE children in Years 5 and 6; again, these differences were not statistically significant. While this suggests that the FLE children made greater progress between Year 4 and Year 5, this should be interpreted with caution given that the Year 4 and Year 5 children were two distinct groups of children.

Table 6.4

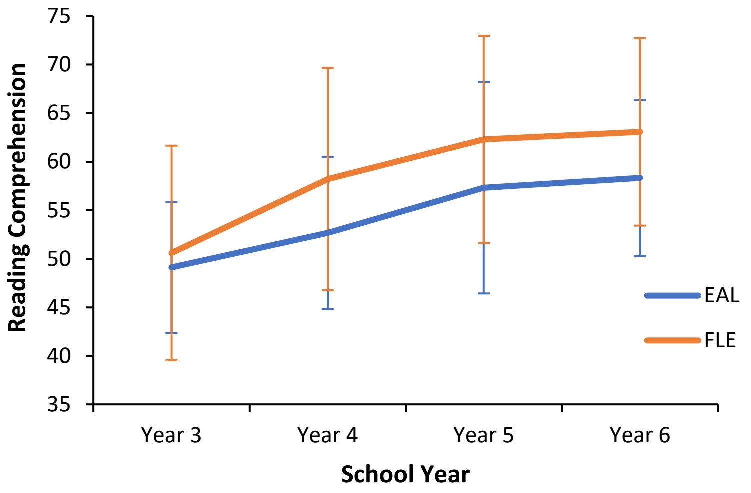
The linguistic abilities of EAL and FLE children across KS2; descriptive statistics

	Year 3			Year 4			Year 5			Year 6		
	EAL	FLE	Effect Size [95% CIs]	EAL	FLE	Effect Size [95% CIs]	EAL	FLE	Effect Size [95% CIs]	EAL	FLE	Effect Size [95% CIs]
Reading Comprehension	49.11 (6.74)	50.60 (11.05)	0.16 [-0.74, 1.06]	52.67 (7.84)	58.20 (11.45)	0.56 [-0.37, 1.47]	57.33 (10.90)	62.29 (10.67)	0.46 [-0.39, 1.30]	58.33 (8.03)	63.07 (9.65)	0.52 [-0.34, 1.37]
General Vocabulary Composite	-1.17 (0.87)	-0.31 (0.69)	1.11* [0.12, 2.07]	-0.72 (0.97)	-0.11 (0.86)	0.67 [-0.27, 1.58]	-0.03 (0.85)	0.54 (0.70)	0.75 [-0.12, 1.61]	-0.12 (0.81)	0.62 (0.72)	0.98* [0.08, 1.86]
Mathematical Vocabulary Knowledge	8.56 (3.28)	9.10 (1.79)	0.21 [-0.70, 1.11]	10.22 (2.68)	10.90 (2.96)	0.24 [-0.67, 1.14]	22.22 (3.19)	24.50 (3.52)	0.67 [-0.20, 1.52]	23.89 (3.55)	24.86 (3.32)	0.28 [-0.56, 1.12]
Decoding Composite	-0.60 (0.72)	-0.99 (1.00)	-0.44 [-1.35, 0.48]	-0.33 (0.56)	-0.66 (0.88)	-0.44 [-1.35, 0.48]	0.28 (1.07)	0.42 (0.83)	0.14 [-0.70, 0.98]	0.31 (1.06)	0.49 (0.80)	0.19 [-0.65, 1.03]

Note: Effect Size is Cohen's *d* with 95% Confidence Intervals [Lower Limit, Upper Limit]. * indicates statistical significance at $p < .05$

Figure 6.1

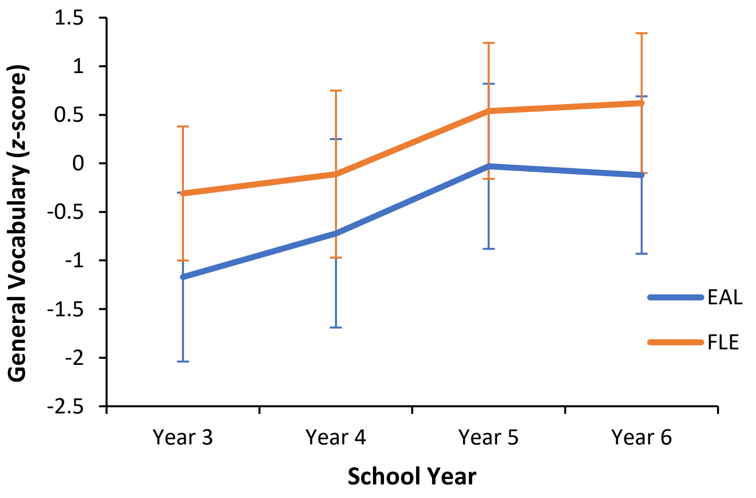
Reading comprehension in EAL and FLE children over the course of KS2



Note: Error bars represent standard deviation

Figure 6.2

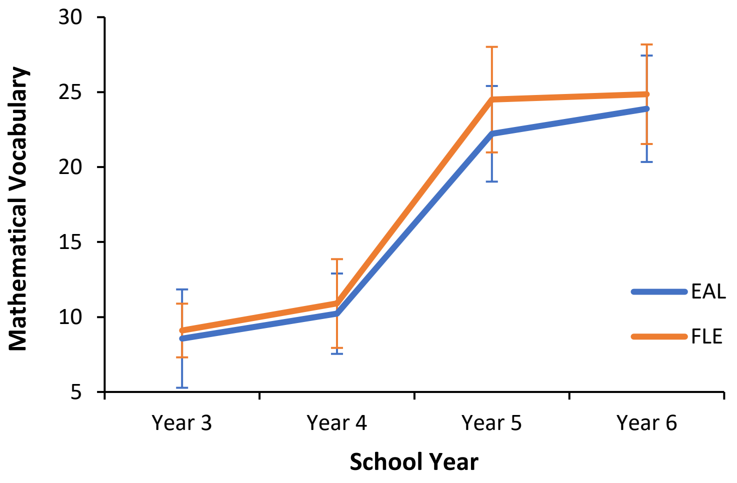
General vocabulary knowledge in EAL and FLE children over the course of KS2



Note: Error bars represent standard deviation

Figure 6.3

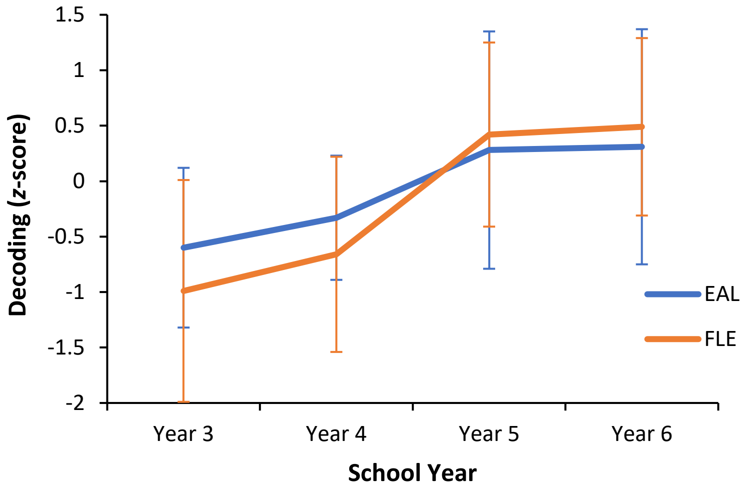
Mathematical vocabulary knowledge in EAL and FLE children over the course of KS2



Note: Error bars represent standard deviation

Figure 6.4

Decoding ability in EAL and FLE children over the course of KS2



Note: Error bars represent standard deviation

6.3.2.3 *Descriptive Statistics: Linguistic Growth over Time*

In order to compare the growth rate over time between the EAL and FLE children for each linguistic variable, additional variables were created which represented each participant's change over time on each linguistic skill which was measured at both time points. This was done by simply subtracting the T1 score for each measure from the T2 score for the same measure. In order to facilitate comparison between the growth rates of the different measures, these growth variables were then standardised through conversion to *z*-scores; given that some measures, such as reading rate, did not have set maximum scores, it was not possible to instead create percentage increase scores in order to achieve this.

Table 6.5 presents skewness and kurtosis values for the standardised growth variables for the whole T2 sample, which were calculated in order to check the distribution of the scores on each variable. Due to its high skewness and kurtosis values, the reading rate growth variable was checked for normality using the Shapiro-Wilk test, and was found to have a non-normal distribution, $p < .001$. The variable was therefore subjected to a square root transformation which rendered the Shapiro-Wilk test non-significant ($p = .085$) and reduced its skewness (0.31) and kurtosis (2.18) values to more acceptable levels.

Table 6.5
Skewness and kurtosis values for the linguistic growth variables; whole T2 sample

Measure	Skewness	Kurtosis
Reading Comprehension	0.78	1.28
Receptive Vocabulary	-0.00	-0.07
Expressive Vocabulary	0.34	-0.59
Mathematical Vocabulary	-0.05	-0.29
Reading Accuracy	0.14	0.46
Reading Rate	1.86	7.02
Word Reading	0.84	-0.03

Table 6.6 presents the mean standardised growth scores for each of the T2 language measures, split by language group, for the whole sample as well as the growth scores from Year 3 to Year 4 and from Year 5 to Year 6 separately. The means for the whole sample demonstrate that the FLE children made somewhat greater gains on average in reading comprehension, receptive vocabulary knowledge, reading accuracy and reading rate, while the EAL children made somewhat greater gains in expressive vocabulary knowledge, mathematical vocabulary knowledge and word reading.

The means for the Year 3-4 group alone largely reflect those of the whole sample, with two exceptions; the EAL children made larger gains in receptive vocabulary knowledge than the FLE children from Year 3 to Year 4, while the FLE children made larger gains in mathematical vocabulary knowledge than the EAL children. The means for the Year 5-6 group show a predominantly different pattern to those of the whole sample, with only gains in receptive vocabulary knowledge, mathematical vocabulary knowledge and reading accuracy showing the same pattern as for the whole sample. Instead, the EAL children made greater gains on the measures of reading comprehension and reading rate between Year 5 and Year 6, while the FLE children made greater gains in expressive vocabulary knowledge and word reading between Year 5 and Year 6. These differences are of course simply descriptive; inferential analyses comparing the rate of growth for each linguistic variable between the two language groups are carried out in Section 6.3.1.5.

Table 6.6
Mean (SD) standardised growth scores for the linguistic measures; whole sample, Year 3-4 and Year 5-6

Measure	Whole sample		Year 3-4		Year 5-6	
	EAL	FLE	EAL	FLE	EAL	FLE
Reading Comprehension	-0.09	0.07	0.06	0.54	-0.24	-0.27
	(0.72)	(1.18)	(0.74)	(1.18)	(0.72)	(1.09)
Receptive Vocabulary	-0.02	0.02	0.25	0.13	-0.30	-0.06
	(1.32)	(0.71)	(1.47)	(0.71)	(1.16)	(0.72)
Expressive Vocabulary	0.06	-0.04	0.64	0.05	-0.53	-0.11
	(1.08)	(0.95)	(1.18)	(1.18)	(0.59)	(0.80)
Mathematical Vocabulary	0.18	-0.13	0.18	0.24	0.18	-0.40
	(0.98)	(1.02)	(1.10)	(1.13)	(0.91)	(0.87)
Reading Accuracy	-0.08	0.06	0.26	0.32	-0.42	-0.13
	(1.16)	(0.88)	(0.93)	(0.53)	(1.33)	(1.04)
Reading Rate	-0.01	0.01	0.01	0.90	-0.03	-0.63
	(0.68)	(1.20)	(0.77)	(1.01)	(0.64)	(0.89)
Word Reading	0.03	-0.02	0.63	0.24	-0.58	-0.20
	(1.13)	(0.91)	(1.22)	(0.97)	(0.64)	(0.85)

6.3.2.4 Correlations between the Linguistic Growth Variables

In order to investigate the relationships between the linguistic growth variables, partial correlations were calculated between all seven linguistic growth variables, controlling for year group. In addition, two variables generated from the home learning questionnaires were correlated with the linguistic growth measures. These variables represented the total number of hours typically spent participating in home learning activities every week for the children who were not attending school full-time, and the frequency with which the sample engaged in reading at home during the school closures.

As can be seen in Table 6.7, none of the linguistic growth variables were strongly intercorrelated; in fact, amongst the linguistic growth variables the only significant correlations observed were between growth in reading comprehension and growth in expressive vocabulary, reading rate and word reading. For this reason, it was not considered appropriate to create composite variables from the linguistic growth variables.

A moderate correlation was found between the frequency of home learning participation and reading during the school closures. However, these two variables were not significantly correlated with any linguistic growth variables with the exception of a significant weak negative correlation between reading frequency during the school closures and growth in reading rate.

Table 6.7

Partial correlations between the linguistic growth and home learning variables, controlling for year group

	1.	2.	3.	4.	5.	6.	7.	8.
1. Reading Comprehension								
2. Receptive Vocabulary	-.09							
3. Expressive Vocabulary	.32*	.07						
4. Mathematical Vocabulary	.20	-.15	.28					
5. Reading Accuracy	.00	.19	.10	.06				
6. Reading Rate	.34*	-.05	-.22	-.19	.09			
7. Word Reading	.38*	.02	.10	.03	.09	.12		
8. Home Learning Participation	.05	-.08	.02	.07	-.02	.08	.29	
9. Reading at Home	-.09	.04	.15	.21	-.14	-.32*	-.07	.47**

Note. * indicates $p < .05$, ** indicates $p < .01$, *** indicates $p < .001$

6.3.2.5 EAL and FLE Differences on the Linguistic Growth Variables

Due to the fact that no composite variables were made for the linguistic growth variables, the growth rates of the EAL and FLE children could not be compared using multivariate analysis given the large number of outcome variables and the relatively small sample size. Instead, individual one-way ANCOVAs, controlling for year group, were carried out for each standardised linguistic growth variable, in order to determine whether any group differences existed between the EAL and FLE children across the whole T2 sample and to thus answer research question 6b. Prior to running the analyses, the suitability of each linguistic growth variable for ANCOVA analysis was examined and all variables were found to meet the assumptions necessary to perform ANCOVA.

The results of these analyses are presented in Table 6.8. These results reveal that there was no significant difference between the EAL and FLE children in growth over time for any linguistic variable. This suggests that linguistic growth over time is similar for EAL and FLE across Years 3 and 5. However, two of the analyses revealed a significant effect of year group, suggesting that the group differences in linguistic growth between EAL and FLE children might differ somewhat for the Year 3-4 group and the Year 5-6 group. Specifically, an effect of year group was found for reading rate, $F(1, 39) = 9.52$, $p = .004$, and for word reading, $F(1, 39) = 6.99$, $p = .012$.

Table 6.8
ANCOVA results for the linguistic growth variables; combined sample

Variable	EAL Mean	FLE Mean	*F*	*p*	Effect Size [95% CIs]
Reading Accuracy	-0.08 (1.16)	0.06 (0.88)	0.36	.551	0.14 [-0.47, 0.75]
Reading Rate	-0.01 (0.68)	0.01 (1.20)	0.11	.744	0.02 [-0.59, 0.63]
Reading Comprehension	-0.09 (0.72)	0.07 (1.18)	0.48	.494	0.16 [-0.45, 0.77]
Word Reading	0.03 (1.13)	-0.02 (0.91)	0.01	.944	-0.04 [-0.65, 0.57]
Expressive Vocabulary	0.06 (1.08)	-0.04 (0.95)	0.03	.870	-0.10 [-0.71, 0.51]
Receptive Vocabulary	-0.02 (1.32)	0.02 (0.71)	0.05	.822	0.04 [-0.57, 0.65]
Mathematical Vocabulary	0.18 (0.98)	-0.13 (1.02)	0.82	.372	-0.31 [-0.92, 0.31]

Note: Effect Size is Cohen's *d* with 95% Confidence Intervals [Lower Limit, Upper Limit].

Further analyses were carried out in order to compare the growth in reading rate and word reading over time between the EAL and FLE children in the Year 3-4 group and the Year 5-6 group separately. Independent samples *t*-tests revealed there to be no significant difference between the language groups within either year group in growth in word reading ability, $p > .05$ for both year groups. While this was also true for the Year 5-6 group when comparing growth in reading rate between the language groups, $p < .05$, the Year 3-4 FLE children ($M = 0.90$, $SD = 1.01$) showed significantly faster growth in reading rate over time than their EAL peers ($M = 0.01$, $SD = 0.77$), $t(17) = 2.15$, $p = .046$, $d = 0.99$ [0.02, 1.94], suggesting that FLE children make faster progress in reading fluency between Year 3 and Year 4 than their EAL peers.

6.3.2.6 The Longitudinal Predictors of Reading Comprehension

In order to address research question 7, the longitudinal predictors of reading comprehension in EAL and FLE children were examined using multiple regression analysis. Prior to this, the relationships between the T1 predictors and T2 reading comprehension were examined for the whole sample and for the language groups separately through partial correlation analyses, controlling for year group; the results of these analyses are presented in Table 6.9. The T1 predictors included are the T1 decoding composite and the T1 vocabulary composite, the details of which can be found in Section 4.3.2, as well as T1 non-verbal ability. These analyses show T1 vocabulary to have the strongest correlation with T2 reading comprehension across all three groups. Both T1 word reading and T1 non-verbal ability showed positive significant correlations with T2 reading comprehension in all three groups, with the exception that T1 decoding was not significantly correlated with later reading comprehension in the FLE group.

Table 6.9
Partial correlations, controlling for year group, between the T1 predictors and T2 reading comprehension

	T2 Reading Comprehension		
	Whole Sample	EAL	FLE
T1 Decoding	.31*	.52*	.34
T1 Vocabulary	.71***	.66**	.74***
T1 Non-verbal Ability	.48***	.52*	.48*

Note. * indicates $p < .05$, ** indicates $p < .01$, *** indicates $p < .001$

Given the reduced sample at T2 and in order to maximise statistical power, a single regression analysis was run on the combined sample, entering year group and language group into the model as predictors. All predictor variables were entered into the model simultaneously. The assumptions of multiple linear regression were checked and no violations of the assumptions were identified.

The results of the multiple regression analysis can be found in Table 6.10. The model significantly accounted for 54% of the variance in T2 reading comprehension, $F(5, 34.15) = 10.46$, $p < .001$. T1 vocabulary was a strong predictor of T2 reading comprehension, uniquely accounting for 18% of the variance. In addition, T1 non-verbal ability was a significant predictor of T2 reading comprehension, uniquely accounting for a further 4% of the variance. However, decoding was not found to be a significant unique predictor. In addition, year group was a significant predictor, suggesting that the longitudinal predictors of reading comprehension differ between the Year 3-4 group and the Year 5-6 group, but language group was not a significant predictor, suggesting that the longitudinal predictors of reading comprehension do not differ between EAL and FLE children.

Table 6.10
Multiple regression model predicting T2 reading comprehension; whole sample

Predictor	Adjusted R^2	β (*SE*)	*t*	*p*	Unique R^2
	.54				
Year Group		-.42 (.16)	-2.68	.007	.08
Language Group		-.01 (.13)	-0.06	.949	< .01
T1 Decoding		.03 (.13)	0.21	.835	< .01
T1 Vocabulary		.82 (.21)	3.94	< .001	.18
T1 Non-verbal Ability		.29 (.15)	1.96	.050	.04

Note. Unique R^2 is represented by squared semi-partial correlations

Despite the significant effect of year group found in the initial longitudinal model, further regression analyses for each year group separately were not carried out, given the reduced sample size at T2 and the further reductions that doing so would cause. However, to give some indication of the relationships between the T1 predictors and T2 reading comprehension for the year groups separately, longitudinal partial correlation analyses, controlling for language group, were carried out. The results of these are shown in Table 6.11. While both T1 decoding and T1 vocabulary knowledge were significantly related to T2 reading comprehension in the younger group, of the two, only vocabulary knowledge was significantly related to T2 reading comprehension in the older group. This suggests that the longitudinal contribution of decoding to reading comprehension declines with age, while the contribution of vocabulary knowledge strengthens in turn. In addition, the contribution of non-verbal ability was significant in the older group but not in the younger group.

Table 6.11

Partial correlations, controlling for language group, between the T1 predictors and T2 reading comprehension, split by year group

	T2 Reading Comprehension	
	Year 3-4	Year 5-6
T1 Decoding	.49*	.32
T1 Vocabulary	.64**	.72***
T1 Non-verbal Ability	.46	.52*

Note. * indicates $p < .05$, ** indicates $p < .01$, *** indicates $p < .001$

6.3.2.7 Summary

In summary, the EAL children showed somewhat lower mean levels of reading comprehension, general vocabulary knowledge and mathematical vocabulary knowledge than their FLE peers across the course of KS2. While the EAL children showed stronger mean decoding skills than their FLE peers in Years 3 and 4, the opposite was true for the Year 5 and Year 6 children. The EAL and FLE children were found to make similar progress over time in reading comprehension as well as in vocabulary knowledge and decoding. The longitudinal predictors of reading comprehension were found to be comparable between the EAL and FLE children. For the whole sample, vocabulary knowledge was found to be a unique longitudinal predictor of reading comprehension while decoding ability was not. Correlation analyses revealed a stronger longitudinal association between decoding ability and reading comprehension for the younger group than for the older group, while vocabulary knowledge was found to be more strongly related to later reading comprehension in the older group than in the younger group. In addition, neither the frequency of home learning participation nor the frequency of reading at home during the school closures as reported by the children themselves were significantly related to linguistic growth over time.

6.3.3 The Development of Mathematical Ability in EAL and FLE Children

Turning now to mathematics, this section details the results of a series of analyses investigating the development of mathematical ability in EAL and FLE children. Firstly, the developmental trajectories of arithmetic ability and mathematical WPS between Year 3 and Year 6 will be investigated through the use of descriptive statistics. Subsequently, the growth over time in arithmetic ability and mathematical WPS ability in the EAL and FLE children will be compared. Finally, the longitudinal predictors of both arithmetic ability and mathematical WPS will be determined.

6.3.3.1 Correlations between the T2 Mathematical Variables and the Creation of an Arithmetic Composite

The mathematical abilities measured at T2 were arithmetic computation, mathematical WPS and arithmetic fluency. The relationships between these measures were examined for the T2 sample using partial correlation analysis, controlling for year group; the results of this analysis can be found in Table 6.12. All three measures were highly intercorrelated, showing strong positive correlations.

Table 6.12
Partial correlations between the T2 mathematical measures, controlling for year group

	1.	2.	3.
1. Arithmetic Computation			
2. Mathematical WPS	.82***		
3. Arithmetic Fluency	.77***	.80***	

Note. * indicates $p < .05$, ** indicates $p < .01$, *** indicates $p < .001$

In order to facilitate examination of the developmental trajectories of arithmetic ability and mathematical WPS across the year groups, an "Arithmetic" composite variable was created, comprising the bespoke arithmetic computation task and arithmetic fluency, as for the T1 arithmetic composite created in Section 5.3.2. The composite was created by converting scores on the two relevant tasks to *z*-scores, and taking the mean of these *z*-scores.

6.3.3.2 The Developmental Trajectories of Mathematical Skills in EAL and FLE Children

In order to examine the developmental trajectories of arithmetic ability and mathematical WPS in EAL and FLE children and thus answer research question 8a, descriptive statistics for the arithmetic composite and mathematical WPS scores were calculated for the EAL and FLE children who participated at both T1 and T2 separately within each year group. In addition, effect sizes (Cohen's *d*) representing the difference between the EAL and FLE children in each year group were calculated and tested inferentially. These statistics are presented in Table 6.13 and are represented visually in Figures 6.5 and 6.6. Again, it is important to remember that these statistics are not strictly longitudinal given the two separate groups of children within the sample. The growth rates of arithmetic and WPS ability in the EAL and FLE children will be compared statistically in Section 6.3.3.5.

On average, the EAL children outperformed their FLE peers in arithmetic ability across Years 3, 4 and 5, while in Year 6, the FLE children marginally outperformed the EAL children. Group differences were much greater for the Year 3-4 group and were in fact statistically significant; conversely the EAL and FLE children in the Year 5-6 group performed very similarly at both time points. In addition, the FLE children made somewhat greater progress in arithmetic ability on average between Year 4 and Year 5, however this should be interpreted with caution given that the Year 4 and Year 5 groups did not consist of the same children. Regarding mathematical WPS, the EAL children scored higher, on average, than their FLE peers in Years 3 and 4, but slightly lower than their FLE peers in Years 5 and 6. These differences, however, were not statistically significant. The EAL children made somewhat quicker progress in mathematical WPS on average between Year 3 and Year 4. Conversely, the FLE children appear to have made quicker progress on average in mathematical WPS than the EAL children between Year 4 and Year 5, however again this should be interpreted with caution given the distinct groups of children.

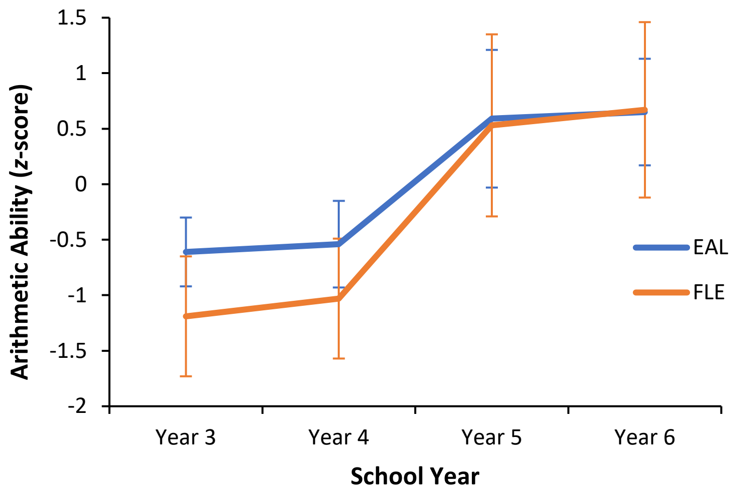
Table 6.13

The mathematical abilities of EAL and FLE children across KS2; descriptive statistics

	Year 3			Year 4			Year 5			Year 6		
	EAL	FLE	Effect Size [95% CIs]	EAL	FLE	Effect Size [95% CIs]	EAL	FLE	Effect Size [95% CIs]	EAL	FLE	Effect Size [95% CIs]
Arithmetic Ability	-0.61 (0.31)	-1.19 (0.54)	-1.28* [-2.26, -0.27]	-0.54 (0.39)	-1.03 (0.54)	-1.03* [-1.98, -0.05]	0.59 (0.62)	0.53 (0.82)	-0.07 [-0.91, 0.76]	0.65 (0.48)	0.67 (0.79)	0.02 [-0.82, 0.86]
Mathematical WPS	7.33 (2.92)	6.40 (5.54)	-0.21 [-1.11, 0.70]	10.67 (4.09)	6.70 (4.16)	-0.96 [-1.90, 0.01]	19.89 (2.85)	21.64 (3.89)	0.50 [-0.36, 1.34]	22.22 (4.24)	23.57 (4.86)	0.29 [-0.55, 1.13]

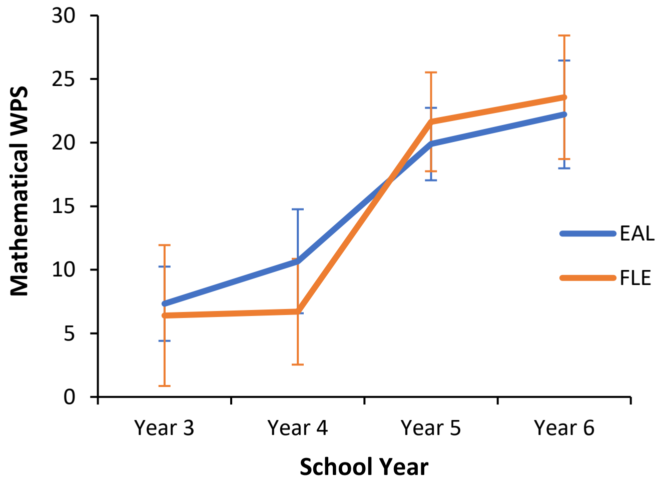
Note: Effect Size is Cohen's *d* with 95% Confidence Intervals [Lower Limit, Upper Limit]. * indicates statistical significance at $p < .05$

Figure 6.5
Arithmetic ability in EAL and FLE children over the course of KS2



Note: Error bars represent standard deviation

Figure 6.6
Mathematical WPS in EAL and FLE children over the course of KS2



Note: Error bars represent standard deviation

6.3.3.3 Descriptive Statistics: Mathematical Growth over Time

As in Section 6.3.2.3, additional variables were created which represented each participant's growth over time on each mathematical measure, in order to allow comparison of the mathematical growth between the EAL and FLE children. These variables were created by subtracting the T1 score for each mathematical measure from the T2 score for the same measure for each participant, and subsequently standardising the resulting variable through conversion to *z*-scores to facilitate comparison between the measures.

Skewness and kurtosis values for the mathematical growth variables across the whole T2 sample are shown in Table 6.14. All three mathematical growth variables were considered to be normally distributed based on their skewness and kurtosis values.

Table 6.14
Skewness and kurtosis values for the mathematical growth variables; combined T2 sample

Measure	Skewness	Kurtosis
Arithmetic Computation	-0.22	-0.15
Arithmetic Fluency	-0.06	-0.25
Mathematical WPS	0.37	-0.55

The mean standardised mathematical growth scores, split by language group, for the whole sample as well as for the year groups separately can be found in Table 6.15. Within the whole sample, the EAL children made greater gains on average in arithmetic computation and mathematical WPS, while the FLE children made greater gains in arithmetic fluency. The same pattern was found in the year groups separately, with the exception that in the Year 3-4 group, the FLE children made greater gains over time in arithmetic computation than the EAL children did.

Table 6.15
Mean (SD) standardised mathematical growth scores: whole sample, Year 3-4 and Year 5-6

Measure	Whole sample		Year 3-4		Year 5-6	
	EAL	FLE	EAL	FLE	EAL	FLE
Arithmetic Computation	0.14	-0.10	0.14	0.30	0.14	-0.40
	(1.12)	(0.91)	(1.04)	(0.83)	(1.27)	(0.87)
Arithmetic Fluency	-0.22	0.16	-0.40	-0.36	-0.03	0.54
	(0.90)	(1.06)	(0.94)	(1.12)	(0.86)	(0.86)
Mathematical WPS	0.37	-0.28	0.57	-0.66	0.16	0.00
	(0.93)	(0.97)	(0.86)	(0.90)	(1.01)	(0.96)

6.3.3.4 Correlations between the Mathematical Growth Variables

The relationships between the mathematical growth variables were examined through partial correlation analysis, controlling for year group. In addition, the frequency of home learning participation and the frequency of reading at home during the COVID-19 school closures were both correlated with the mathematical growth variables. The results of these analyses are presented in Table 6.16. None of the mathematical growth variables were found to be significantly intercorrelated. Therefore, an arithmetic composite variable was not created for the growth scores. In addition, neither of the home learning variables were significantly correlated with any of the mathematical growth variables.

Table 6.16
Partial correlations between the mathematical growth and home learning variables, controlling for year group

	1.	2.	3.	4.
1. Arithmetic Computation				
2. Arithmetic Fluency	.19			
3. Mathematical WPS	-.12	.12		
4. Home Learning Participation	-.06	.17	-.05	
5. Reading at Home	-.15	.25	.03	.47**

Note. * indicates $p < .05$, ** indicates $p < .01$, *** indicates $p < .001$

6.3.3.5 EAL and FLE Differences on the Mathematical Growth Variables

In order to compare the mathematical growth over time of EAL and FLE children and thus answer research question 8b, a one-way MANCOVA, controlling for year group, was carried out for the whole sample, in order to maximise statistical power. The outcome variables entered into the model were growth over time in arithmetic computation, arithmetic fluency and mathematical WPS. The assumptions for performing a MANCOVA were checked prior to the analysis, and no violations were identified. The results of the MANCOVA are presented in Table 6.17. The results show a significant effect of language group on the combined mathematical growth variables, $V = .19$, $F(3, 37) = 2.98$, $p = .044$. Overall, year group did not have a significant effect on the combined outcome variables, $V = .18$, $F(3, 37) = 2.66$, $p = .062$. In particular, the EAL group made significantly faster progress over time in mathematical WPS than the FLE group, $F(1, 39) = 4.76$, $p = .035$, with a medium effect size. Conversely, there was no significant difference in the growth rate of arithmetic computation or arithmetic fluency between the EAL and FLE children. Given that there was no significant effect of year group on the outcome measures, no further analyses were carried out.

Table 6.17
MANCOVA results for the mathematical growth variables; combined year groups

Variable	EAL Mean	FLE Mean	*F*	*p*	Effect Size [95% CIs]
Arithmetic Computation	0.14	-0.10	0.46	.502	-0.24
	(1.12)	(0.91)			[-0.85, 0.37]
Arithmetic Fluency	-0.22	0.16	1.20	.279	0.38
	(0.90)	(1.06)			[-0.24, 1.00]
Mathematical WPS	0.37	-0.28	4.76	.035	-0.67
	(0.93)	(0.97)			[-1.30, -0.04]

Note: Effect Size is Cohen's *d* with 95% Confidence Intervals [Lower Limit, Upper Limit].

6.3.3.6 The Longitudinal Predictors of Mathematical Performance

In order to examine the longitudinal predictors of mathematical performance, specifically arithmetic computation and mathematical WPS, in EAL and FLE children and thus answer research question 9, several multiple regression analyses were carried out. Prior to this, the partial correlations, controlling for year group, between the T1 predictors, T2 arithmetic computation and T2 WPS were examined for the whole sample and for the language groups separately. Specifically, the T1 predictors included were reading comprehension, arithmetic fluency, general vocabulary knowledge, mathematical vocabulary knowledge, decoding and non-verbal ability; these predictors were again classified as either academic or cognitive or linguistic. The results of these analyses are presented in Table 6.18.

Across the whole sample, all T1 predictor variables were found to correlate significantly with both T2 arithmetic computation and mathematical WPS, although more strongly with WPS. While the majority of T1 predictors correlated strongly with T2 arithmetic computation for the FLE children, the only T1 variable which correlated significantly with T2 arithmetic computation for the EAL children was arithmetic fluency. The correlates of T2 mathematical WPS were largely comparable for the EAL and FLE children, with the exception that T1 reading comprehension was not a significant predictor of T2 WPS for the EAL children.

Table 6.18
Partial correlations, controlling for year group, between the T1 predictors and T2 mathematical performance

	T2 Arithmetic Computation			T2 Mathematical WPS		
	Whole sample	EAL	FLE	Whole sample	EAL	FLE
Academic Skills						
T1 Reading Comprehension	.43**	-.19	.70***	.54***	.32	.72***
T1 Arithmetic Fluency	.77***	.69**	.80***	.82***	.79***	.87***
Cognitive or Linguistic Skills						
T1 General Vocabulary	.33*	.22	.72***	.53***	.70***	.75***
T1 Mathematical Vocabulary	.51***	.10	.80***	.59***	.52*	.72***
T1 Decoding	.56***	.27	.65***	.71***	.60**	.78***
T1 Non-verbal Ability	.35*	.29	.40	.52***	.62**	.48*

Note. * indicates $p < .05$, ** indicates $p < .01$, *** indicates $p < .001$

In light of the reduced T2 sample size, each multiple regression analysis was run on the combined sample, entering both year group and language group into the model as additional predictors. All predictors were entered into all models simultaneously. In each case, no violations of the assumptions of multiple regression analysis were identified. For each mathematical task, the academic and cognitive or linguistic predictors were analysed separately.

Firstly, the longitudinal predictors of T2 arithmetic computation were examined. The results of these analyses are presented in Table 6.19. Model 1 was found to significantly account for 91% of the variance in T2 arithmetic computation, $F(4, 37) = 106.33$, $p < .001$. T1 arithmetic fluency was found to significantly predict T2 arithmetic computation, uniquely accounting for 8% of the variance, while T1 reading comprehension was not found to be a unique significant predictor of T2 arithmetic computation. In addition, year group was found to be a significant predictor of T2 arithmetic computation while language group was not; this suggests that the longitudinal academic predictors of arithmetic computation differ between the Year 3-4 group and the Year 5-6 group but not between EAL and FLE children.

Model 2 significantly accounted for 86% of the variance in T2 arithmetic computation, $F(6, 33.16) = 43.36$, $p < .001$. Of the cognitive and linguistic variables, T1 mathematical vocabulary knowledge and T1 decoding were found to significantly predict T2 arithmetic computation, both uniquely accounting for 1% of the variance, while general vocabulary knowledge and non-verbal ability were not unique significant predictors. In addition, year group, but not language group, was found to be a significant predictor, again suggesting that the longitudinal cognitive and linguistic predictors of arithmetic computation differ between the year groups but not between the language groups. Given the number of variables and the reduced sample size at T2, the results of this analysis should be interpreted with caution.

Table 6.19

Longitudinal multiple regression models predicting T2 arithmetic computation; whole sample

Predictor	Adjusted R^2	β (*SE*)	*t*	*p*	Unique R^2
Model 1 – Academic Predictors	.91				
Year Group		.60 (.06)	10.08	< .001	.22
Language Group		.01 (.05)	0.17	.863	< .01
T1 Reading Comprehension		.10 (.05)	1.93	.054	< .01
T1 Arithmetic Fluency		.39 (.07)	6.18	< .001	.08
Model 2 – Cognitive & Linguistic Predictors	.86				
Year Group		.36 (.17)	2.10	.036	.01
Language Group		.10 (.07)	1.47	.142	< .01
T1 General Vocabulary		.01 (.10)	0.10	.921	< .01
T1 Mathematical Vocabulary		.44 (.22)	2.02	.044	.01
T1 Decoding		.15 (.07)	2.02	.043	.01
T1 Non-verbal Ability		.10 (.08)	1.20	.230	< .01

Note. Unique R^2 is represented by squared semi-partial correlations

Subsequently, the longitudinal predictors of mathematical WPS were examined in the same way. The results of these analyses can be found in Table 6.20. Model 1 significantly accounted for 92% of the variance in T2 mathematical WPS, $F(4, 37) = 120.78$, $p < .001$. Both T1 reading comprehension and T1 arithmetic fluency significantly predicted T2 WPS, uniquely accounting for 3% and 11% of the variance respectively. In addition, year group was a significant predictor while language group was not. Accordingly, this suggests that the longitudinal academic predictors of mathematical WPS differ by year group but not by language group.

Model 2 was found to significantly account for 91% of the variance in T2 mathematical WPS, $F(6, 33.16) = 68.27$, $p < .001$. Of the cognitive and linguistic predictors, T1 decoding and T1 non-verbal ability were found to be significant predictors of T2 WPS, uniquely accounting for 3% and 2% of the variance respectively. Neither type of T1 vocabulary knowledge was found to significantly predict T2 WPS. Finally, year group was a significant predictor of T2 WPS while language group was not. Again, in light of the number of variables in Model 1 and the reduced sample size at T2, these results should be interpreted with caution.

Table 6.20

Longitudinal multiple regression models predicting T2 mathematical WPS; whole sample

Predictor	Adjusted R^2	β (*SE*)	*t*	*p*	Unique R^2
Model 1 – Academic Predictors	.92				
Year Group		.49 (.05)	9.82	< .001	.19
Language Group		-.02 (.04)	1.17	.240	< .01
T1 Reading Comprehension		.16 (.05)	3.75	< .001	.03
T1 Arithmetic Fluency		.47 (.06)	7.59	< .001	.11
Model 2 – Cognitive & Linguistic Predictors	.91				
Year Group		.33 (.14)	2.35	.019	.01
Language Group		.10 (.06)	1.75	.080	< .01
T1 General Vocabulary		.14 (.08)	1.60	.109	< .01
T1 Mathematical Vocabulary		.27 (.18)	1.55	.121	< .01
T1 Decoding		.23 (.06)	3.93	< .001	.03
T1 Non-verbal Ability		.19 (.07)	2.80	.005	.02

Note. Unique R^2 is represented by squared semi-partial correlations

Although a significant effect of year group was found in all longitudinal multiple regression analyses, it was not feasible to conduct further regression analyses for each year group separately given the already reduced sample at T2. Instead, longitudinal partial correlation analyses, controlling for language group, were carried out for each year group separately; the results of these analyses are shown in Table 6.21. Regarding T2 arithmetic computation, it seems that while T1 arithmetic fluency is a strong correlate for both year groups, T1 reading comprehension is only related to T2 arithmetic computation in the younger group. Accordingly, the contributions of T1 general vocabulary knowledge and decoding to T2 arithmetic computation decrease over time, while T1 mathematical vocabulary knowledge and non-verbal ability become more related to T2 arithmetic computation over time. Regarding T2 mathematical WPS, it seems that while the contribution of arithmetic fluency remains stable over time, the contribution of reading comprehension decreases with age. The relationships between T1 vocabulary knowledge and T2 WPS seem to strengthen slightly with age, while the relationship between T1 decoding and T2 WPS seems to decrease with age. In addition, non-verbal ability seems to be more important to WPS in older children.

Table 6.21
Partial correlations, controlling for language group, between the T1 predictors and T2 mathematical performance

	T2 Arithmetic Computation		T2 Mathematical WPS	
	Year 3-4	Year 5-6	Year 3-4	Year 5-6
Academic Skills				
T1 Reading Comprehension	.74***	.35	.71***	.50*
T1 Arithmetic Fluency	.78***	.77***	.87***	.86***
Cognitive or Linguistic Skills				
T1 General Vocabulary	.60**	.48*	.70***	.74***
T1 Mathematical Vocabulary	.40	.64**	.62**	.64**
T1 Decoding	.67**	.47*	.76***	.67***
T1 Non-verbal Ability	.19	.45*	.36	.64**

Note. * indicates $p < .05$, ** indicates $p < .01$, *** indicates $p < .001$

6.3.3.7 Summary

In summary, the EAL children demonstrated stronger arithmetic computation and mathematical WPS abilities on average than their FLE peers across Year 3 and Year 4. In Year 5 and Year 6, the EAL and FLE children performed very similarly on the arithmetic computation task, while the EAL children fell behind in mathematical WPS. Overall, there was no significant difference in the mathematical growth rates of the EAL and FLE children, with the exception that the EAL children made significantly faster progress in mathematical WPS than their FLE peers. Furthermore, the longitudinal predictors of both arithmetic computation and mathematical WPS were comparable between the EAL and FLE children. Across the combined sample, arithmetic fluency alone was a longitudinal academic predictor of arithmetic computation, while the cognitive and linguistic longitudinal predictors were found to be mathematical vocabulary knowledge and decoding. Both reading comprehension and arithmetic fluency were found to be longitudinal academic predictors of mathematical WPS, while the longitudinal cognitive and linguistic predictors of WPS were revealed to be decoding and non-verbal ability. Finally, neither home learning variable was significantly related to mathematical growth over time.

6.4 Discussion

This chapter aimed to investigate the development of a range of linguistic and mathematical abilities in EAL and FLE children over the course of KS2, as well as to compare the longitudinal predictors of reading comprehension, arithmetic computation and mathematical WPS between the two language groups. This was achieved through the analysis of data collected at T2 during the current study and the corresponding T1 data. Regarding the developmental trajectories of linguistic skills, it was hypothesised that the EAL children would have weaker reading comprehension and vocabulary skills than their FLE peers across the course of KS2, and that the growth in these skills over time would be slower for the EAL children. Conversely, it was hypothesised that the decoding skills of the EAL and FLE children would follow a similar developmental trajectory. The longitudinal predictors of reading comprehension were anticipated to be vocabulary knowledge and decoding ability for both language groups, with the contribution of decoding ability decreasing with age. In addition, vocabulary knowledge was expected to be a stronger longitudinal predictor of reading comprehension for the EAL children than for the FLE children. Regarding the mathematical performance of the EAL and FLE children over time, it was hypothesised that the developmental trajectories of arithmetic computation would be comparable between the language groups while the EAL children would show consistently lower WPS skills and slower growth in WPS over time than the FLE children. The longitudinal predictors of mathematical ability were expected to be comparable between the language groups. In particular, arithmetic fluency and decoding ability were expected to predict later arithmetic computation, while reading comprehension, arithmetic fluency, general vocabulary knowledge, mathematical vocabulary knowledge, decoding ability and non-verbal ability were expected to predict later mathematical WPS. The results of the statistical analyses presented in Section 6.3 reflect these predictions to some extent. The current section will discuss the findings from the current chapter in light of the hypotheses and the relevant previous research. The educational implications of the results will also be discussed.

Firstly, the educational experiences of the sample during the COVID-19 school closures were summarised in order to contextualise the T2 data, given the unique academic year that the sample had experienced. The results of the home learning questionnaire revealed that almost all T2 participants either engaged in home learning or attended school full time, however the frequency of home learning engagement was very variable within the sample. Encouragingly, no significant differences in the frequency of engagement with home learning activities or reading during the school closures were found between the EAL and FLE children, despite evidence from the USA that EAL children engaged with home learning less than FLE children (Sugarman & Lazarín, 2020). Of course, it should be noted that these variables were generated from the children's own responses to the questionnaire and are therefore not wholly reliable; it is likely that more reliable estimates of such measures would have been obtained from the parent questionnaire, had the response rate been higher. Nevertheless, the EAL children in the current study were found to make similar or indeed faster progress in their linguistic and mathematical abilities over time in comparison to their FLE peers, suggesting that the EAL children were not disproportionately affected by the school closures. Indeed, no significant correlations were found between the frequency of academic engagement at home and the academic growth of the sample. Unfortunately, the design of the current study did not allow for any comparisons to be made between the academic performance of the T2 sample and the typical academic performance of children of the same age before the COVID-19 pandemic, meaning relative losses in learning could not be identified or quantified. This fact aside, the current study encouragingly suggests there to have been no significant differences in the home learning experiences of EAL and FLE children in England nor in their academic growth over the first period of school closures, while acknowledging the potential unreliability of the home learning data and the small sample size. Future research utilising a larger sample, more reliable home learning measures and typical pre-pandemic academic achievement data would likely have the means to assess the effect of the school closures on the academic achievement of EAL and FLE children in England more accurately.

Turning now to the development of linguistic skills over time in EAL and FLE children, the developmental trajectories examined in Section 6.3.2.2 were somewhat in line with the predictions made. In line with expectations as well as with previous longitudinal research (e.g., Burgoyne et al., 2011; Hutchinson et al., 2003), the EAL children showed consistently lower mean reading comprehension scores than their FLE peers across the course of KS2, although these differences were not found to be statistically significant, reflecting findings from Chapter 4. Contrary to the hypotheses, the EAL and FLE children made comparable progress over time in reading comprehension. Given that the literature shows very mixed results regarding the growth rate of reading comprehension in EAL and FLE children, this finding is not wholly surprising. It is possible that the reading comprehension growth of EAL learners is somewhat dependent on their PiE levels, with highly proficient EAL learners making similar or even faster progress in comparison to their FLE peers and EAL learners with lower PiE making slower progress. Indeed, the achievement gap in reading comprehension between EAL and FLE children has been found to be larger when considering EAL children with lower levels of PiE (e.g., Halle et al., 2012; Kieffer, 2008). While examining the developmental trajectories of reading comprehension by EAL PiE level was not in the scope of the current study, future research carried out in the UK context should strive to consider the PiE levels of EAL children when examining their developmental trajectories of reading comprehension.

Also in line with expectations and the results of previous research (e.g., Burgoyne et al., 2011; Hutchinson et al., 2003; Mahon & Crutchley, 2006), the current study found the EAL children to score consistently lower, on average, than their FLE peers in general vocabulary knowledge. This gap in vocabulary knowledge was statistically significant in Year 3 and Year 6 only. While these results suggest that the achievement gap narrows slightly over time between Year 3 and Year 5, in line with the majority of the previous research (e.g., Mahon & Crutchley, 2006), the rewidening of the achievement gap between Year 5 and Year 6 runs contrary to what has been found in previous research. It is possible that the school closures caused by the COVID-19 pandemic are the reason for the vocabulary loss observed between Year 5 and Year 6 in the EAL children in the current study, due to a decrease in exposure to English during this time. Despite these observed nuances in the developmental trajectories of general vocabulary knowledge in EAL and FLE children, the current study found there to be no significant difference in the overall vocabulary knowledge growth over time between the language groups. Given that there is evidence that the extent to which EAL children lag behind their FLE peers in vocabulary knowledge is dependent on their use of English in the home (Ribot et al., 2018), it is possible that this is also true for their growth in vocabulary knowledge over time; future research should aim to consider English use in the home when studying the development of vocabulary knowledge over time in EAL learners.

As hypothesised, the EAL children also consistently scored lower, on average, than their FLE peers in mathematical vocabulary knowledge across KS2, however contrary to expectations, these differences were marginal and not statistically significant. While there is no existing research comparing the mathematical vocabulary knowledge of EAL and FLE children over a number of years, this finding reflects the non-significant differences found in Chapter 4 and is thus again in disagreement with some existing literature finding a general EAL disadvantage in mathematical vocabulary knowledge (Kazima, 2007; Powell et al., 2020) but in accordance with the findings of Xu and colleagues (2021). The comparable mathematical vocabulary knowledge of the EAL and FLE children can perhaps be explained by the fact that the majority of the EAL children in the current study had been attending primary schools in England since the age of 4, and thus had experienced the same mathematical education as the FLE children. The current study found the mean difference in mathematical vocabulary knowledge scores to be greatest for the Year 5 children, perhaps reflecting the growing complexity and specificity of the mathematical vocabulary learned during primary school. Despite this, the trajectories of mathematical vocabulary knowledge development were remarkably similar for the EAL and FLE children, and accordingly, no significant difference in the growth of mathematical vocabulary knowledge over time was found.

In line with expectations, and in accordance with previous research (e.g., Burgoyne et al., 2011; Lesaux et al., 2007), the decoding skills of the EAL and FLE children followed similar trajectories, with no significant difference between the EAL and FLE children in any year group and nor in the overall rate of growth in decoding abilities over time. This extends the findings of Chapter 4, showing that there is no difference in decoding ability between EAL and FLE children across all KS2 years.

The results of the analyses examining the longitudinal predictors of reading comprehension were somewhat in line with the hypotheses. As predicted, and in line with previous research (e.g., Burgoyne et al., 2011; Droop & Verhoeven, 2003), the longitudinal predictors of reading comprehension were not found to differ between the EAL and FLE children. However, while these studies found both decoding ability and language comprehension skills to longitudinally predict reading comprehension in both language groups, the current study found vocabulary knowledge to be the sole longitudinal predictor of reading comprehension for the combined sample. This is perhaps due to a decline in the contribution of decoding ability to reading comprehension, as reported in the literature in both language-minority and monolingual children (e.g., Droop & Verhoeven, 2003; Verhoeven & van Leeuwe, 2012). Indeed, as hypothesised, the current study found a stronger longitudinal association between decoding and reading comprehension in the younger group than in the older group and thus might have found decoding to be a significant predictor of later reading comprehension in the younger group had it been feasible to perform the analysis separately for each age group. In addition, contrary to expectations, the current study found a slightly stronger association between vocabulary knowledge and later reading comprehension in the FLE children than in the EAL children. Although it was not feasible to compare the strength of vocabulary knowledge as a longitudinal predictor of reading comprehension between the language groups in the current study, this finding is somewhat at odds with evidence from the literature suggesting that vocabulary knowledge is a stronger longitudinal predictor of reading comprehension in language-minority children than in monolingual children (e.g., Burgoyne et al., 2011; Droop & Verhoeven, 2003; Geva & Farnia, 2012). Given that evidence from T1 presented in Chapter 4 does agree with the findings from the literature, it is possible that the school closures caused by COVID-19 lie at the root of this longitudinal result. Indeed, the general vocabulary knowledge of the Year 5 EAL children decreased over time, while their reading comprehension ability continued to grow; it is possible that this caused a disparity between the EAL children’s T1 vocabulary knowledge and their T2 reading comprehension abilities. Notwithstanding, the results of the longitudinal regression analyses further highlight the vital importance of vocabulary knowledge to reading comprehension ability in both EAL and FLE children, demonstrating clear longitudinal links across KS2.

Regarding the mathematical development of EAL and FLE children over time, the developmental trajectories examined in Section 6.3.3.2 reflect the hypotheses made to some extent. Firstly, in line with expectations and the limited relevant literature (e.g., Mädamürk et al., 2016), the arithmetic abilities of the EAL and FLE children in Year 5 and Year 6 were very alike, and the arithmetic development of the two language groups followed a similar trajectory, with no significant difference in arithmetic growth evident in either age group. Unexpectedly, however, the EAL children in Year 3 and Year 4 were found to significantly outperform their FLE peers in arithmetic ability. While the arithmetic abilities of the language groups were expected to be comparable, this result is not entirely surprising given the higher mean decoding scores shown by the EAL children in the younger group, a finding not unusual in the literature (e.g., Bowyer-Crane et al., 2017), and the strong role of decoding skills in arithmetic ability shown in Chapter 5 as well as in the literature (e.g., Hecht et al., 2001). Notwithstanding, no EAL disadvantage in arithmetic ability was evident, as hypothesised.

Contrary to expectations, no significant differences in mathematical WPS were evident between the EAL and FLE children within any year group. Furthermore, the EAL children were found to make significantly faster progress in WPS than their FLE peers overall. These results contradict evidence from the literature which suggests a consistent EAL disadvantage in mathematical WPS as well as slower WPS growth in EAL children (Chang et al., 2009; Halle et al., 2012; Mädamürk et al., 2016). However, it should be noted that this evidence, although relevant, does not directly compare the WPS abilities of EAL and FLE children over time and furthermore was not carried out in the UK; for these reasons, its applicability to the current study is limited. In addition, this difference in growth rate seems stem largely from the Year 3 FLE children making very little progress over time in WPS, perhaps due to the COVID-19 school closures. Nonetheless, the similar WPS abilities of the language groups overall are surprising in light of non-longitudinal evidence from the literature showing a clear EAL or language-minority weakness in WPS (e.g., Trakulphadetkrai et al., 2017; Xu et al., 2021). As discussed in detail in Section 5.4, the reasons for this might be methodological or related to the somewhat lower SES of the FLE children in the current study. In addition, there is evidence that a consistent EAL weakness in mathematical WPS over time is only apparent for EAL children with low levels of PiE (Halle et al., 2012); it is possible that examining the developmental trajectories of the EAL children separately for those with high and low PiE might have revealed a greater disparity between the language groups. While no significant differences in WPS were found between the language groups within any year group, it is interesting that the EAL children in Years 3 and 4 showed greater mean scores in WPS than their FLE peers, whilst the opposite was true across Years 5 and 6. It is possible that the EAL advantage in the younger age group was a result of the low arithmetic abilities of the FLE children in that age group, given the importance of arithmetic skills to mathematical WPS (e.g., Andersson, 2007; Lin, 2021), and the low complexity of the mathematical word problems completed by the younger group. Accordingly, it is not surprising that the FLE children showed stronger WPS abilities than the EAL children in the older group, given the comparable arithmetic abilities of the two language groups and the slightly heightened complexity of the mathematical word problems completed by the older group, which incorporated concepts such as time, fractions and currency. Overall, further research is warranted to clarify the developmental trajectories of mathematical WPS in EAL and FLE children in England; this research should aim to directly compare these across the language groups and to consider the PiE levels of the EAL participants.

Finally, the results of the multiple regression analyses assessing the longitudinal predictors of mathematical ability were somewhat in agreement with the hypotheses. The longitudinal predictors of both arithmetic computation and mathematical WPS were found to be comparable between the language groups and to be largely comparable with the key concurrent predictors of arithmetic computation and WPS, as hypothesised based on evidence assessing one or other of the language groups (e.g., Foster et al., 2018; Spencer et al., 2020). As expected, T1 arithmetic fluency was found to be the sole unique predictor of T2 arithmetic computation in both language groups. Also in line with expectations, decoding ability was found to uniquely predict later arithmetic computation. Surprisingly, mathematical vocabulary knowledge was also revealed to be a unique longitudinal predictor of arithmetic computation; this reflects findings from Chapter 5 and might be explained by mathematical vocabulary knowledge acting as a proxy for general mathematical ability given the lack of another mathematical predictor in the model. Furthermore, it should again be noted that, in order to compare more readily between the parallel mathematical tasks, the predictors assessed are not typical predictors of arithmetic computation and thus the inclusion of skills such as processing speed might have rendered the contribution of mathematical vocabulary knowledge non-significant.

In line with the hypotheses and with research investigating the longitudinal predictors of mathematical WPS (e.g., Fuchs et al., 2016; Spencer et al., 2020), both reading comprehension and arithmetic fluency were found to uniquely predict later WPS in both language groups. In the cognitive and linguistic model, only decoding ability and non-verbal ability emerged as unique longitudinal predictors of mathematical WPS; while these were expected to uniquely contribute, it is surprising that neither type of vocabulary knowledge was found to uniquely contribute to later WPS given the clear link between language comprehension and WPS established in the literature and the unique concurrent contribution of general vocabulary knowledge to WPS found in Chapter 5. It is possible that the strong relationship and overlap between general vocabulary knowledge and mathematical vocabulary knowledge resulted in neither measure reaching significance. In addition, the reduced sample size for these analyses caused by the second period of COVID-19 school closures caused a reduction in statistical power as compared to analyses employing only T1 data; perhaps a larger sample would have resulted in a significant unique contribution of T1 vocabulary knowledge to T2 mathematical WPS being revealed. Overall, the results of the longitudinal multiple regression analyses further demonstrate the unique contribution of reading comprehension to mathematical WPS but not to arithmetic computation in both EAL and FLE children. Accordingly, given the weaknesses that EAL and language-minority children typically show in reading comprehension (e.g., Hutchinson et al., 2003; Melby-Lervåg & Lervåg, 2014), it is recommended that schools target the reading comprehension skills of their EAL learners to ensure that they are able to perform to the best of their ability on tests of mathematical ability.

Overall, the results of the current chapter are in line with the hypotheses made to some extent. On average, the EAL children were found to underperform relative to their FLE peers in general vocabulary knowledge and reading comprehension across the course of KS2, while the mathematical vocabulary knowledge, decoding abilities and mathematical skills of the language groups were somewhat comparable. Overall, the EAL and FLE children made comparable academic gains over time. The longitudinal predictors of reading comprehension and mathematical performance were found to be comparable for the EAL and FLE learners. In addition, the contributions of vocabulary knowledge to reading comprehension and of reading comprehension to mathematical WPS were found to remain strong over time. These results again emphasise the importance of targeting language and reading comprehension skills in EAL children and regularly reviewing the support needs of EAL pupils in order to boost their continued academic performance in literacy and mathematics. In light of the longitudinal trajectories of EAL academic achievement demonstrated in this chapter, it is recommended that schools strive to provide this extra support for their EAL pupils from a young age, with the aim to reduce comprehension gaps when they first start to emerge and thus minimise their continued influence on academic achievement. In addition, the results of this chapter provide further evidence in favour of reintroducing the PiE scales in England to ensure that the EAL children most in need of support can be readily identified, given the strong longitudinal links between comprehension skills and academic performance in both literacy and mathematics. Future research should strive to examine the academic development of EAL and FLE children across a larger sample, in order to allow analyses to be carried out for each language and each year group separately, and to consider factors such as the PiE and the English use in the home of its EAL participants. In particular, the developmental trajectories and longitudinal predictors of mathematical ability in EAL and FLE children should be further researched, given the scarcity of such research in the literature. Finally, given the difficulty of interpreting the longitudinal data presented in this chapter due to the COVID-19 pandemic, further research into the effect of COVID-19 on the academic development of EAL and FLE children is warranted. Schools should strive to acknowledge and understand the impact of the pandemic on the educational outcomes of their pupils, and in particular should review the support needs of their EAL pupils in light of the disruption to their learning. Despite the limitations of the current chapter, stemming primarily from the COVID-19 pandemic, the current study is pioneering in its direct comparison of the longitudinal predictors of the mathematical performance of EAL and FLE children, and the analyses presented in this chapter contribute constructively to the literature surrounding the linguistic and mathematical development of EAL learners.

7 General Discussion

In order to advance our understanding of the relationship between the linguistic and mathematical profiles of EAL children, this thesis set out to compare the linguistic and mathematical abilities of EAL and FLE children in England across KS2, and to examine the concurrent and longitudinal predictors of reading comprehension and mathematical performance in both language groups. Implementing a cross-sequential design, the current study first compared the performance of EAL and FLE children in Year 3 and Year 5 on a range of linguistic and cognitive measures including reading comprehension and its subcomponents. Following this, the concurrent predictors of reading comprehension were examined for both language groups. Having established the linguistic profiles of the EAL and FLE children within the study, the mathematical abilities of the two language groups were then compared. Specifically, the study focused on mathematical WPS as well as arithmetic ability. Subsequently, the concurrent predictors of both arithmetic computation and mathematical WPS were examined across both language groups. Finally, within a sub-sample of EAL and FLE participants, the developmental trajectories of the measured linguistic and mathematical abilities were examined, and the longitudinal predictors of reading comprehension and mathematical performance were identified. This chapter will synthesise and discuss the findings from Chapters 4, 5 and 6, before discussing the strengths and limitations of the current study, directions for future research and the educational implications of the current study's findings.

7.1 Key Findings: The Linguistic Abilities of EAL and FLE Children

7.1.1 EAL and FLE Differences in Linguistic Ability

The results of statistical comparisons of the linguistic abilities of EAL and FLE children across the course of KS2 were largely as predicted; overall, the EAL children were found to experience a disadvantage in vocabulary knowledge but to have comparable decoding skills relative to their FLE peers. This finding concurs with and replicates a wealth of research carried out both in the UK and elsewhere (e.g., Babayiğit, 2014; Hutchinson et al., 2003; Melby-Lervåg & Lervåg, 2014) which has found the reading abilities of EAL and language-minority children to be impaired by a weakness in language comprehension but not in decoding ability. The observed EAL disadvantage in English vocabulary knowledge is likely to be explained by their limited exposure to English in comparison to their FLE peers, through their exposure to a language other than English in the home; research has shown a strong correlation between language exposure and vocabulary knowledge in each of a bilingual child's languages (e.g., Thordardottir, 2011). Indeed, a significant correlation between English use outside of school and vocabulary knowledge was found in the current study. As well as the degree to which EAL children are exposed to and use English outside of school, EAL children in the UK also vary highly on many other aspects of bilingualism including age of acquisition of English, language proficiency across different skills such as speaking, reading and writing, typological distance between their two languages and age of arrival into the English education system; these are also likely to contribute to the gap in vocabulary knowledge between EAL and FLE children. This gap in vocabulary knowledge, in conjunction with the comparable decoding skills of the two language groups found in the current study, also reflects the results of international research on cross-language transfer in bilingual children (e.g., Melby-Lervåg & Lervåg, 2011), suggesting that EAL children in the England are indeed able to transfer their decoding skills, but not their language comprehension skills, from their L1 to English.

Further analyses revealed that in particular, EAL children experience a disadvantage in receptive and expressive vocabulary knowledge, as often researched and demonstrated in the literature (e.g., Hutchinson et al., 2003) but not in mathematical vocabulary knowledge. Although an EAL disadvantage in mathematical vocabulary was hypothesised in light of evidence from the literature (Kazima, 2007; Powell et al., 2020), this result is not entirely unexpected given the paucity of research examining mathematical vocabulary knowledge in EAL children, particularly from the UK, and in fact accords with the findings of Xu and colleagues (2021). While the results of the current study suggest that the mathematical vocabulary knowledge of EAL and FLE children in England is comparable across the course of KS2, perhaps because mathematical vocabulary acquisition and use is largely confined to an educational setting, it should be noted that 75% of the EAL children in the current study had been enrolled in UK schools either since the age of 4 or for over two years prior to the start of the study, and that different results might have been found had the sample included more children who had only recently joined the English education system. This further emphasises the importance of considering the degrees of bilingualism within EAL samples in research, rather than relying on binary classifications of bilingualism such as that used within the English education system.

While the current study found an EAL disadvantage in general vocabulary knowledge, analysis of the group differences across the course of KS2 found the EAL children to have significantly lower general vocabulary knowledge in Year 3 and Year 6 only. While the lack of a significant difference in Years 4 and 5 might lie purely in low statistical power given that the EAL children did show lower mean scores throughout KS2, it is possible that, encouragingly, this reflects a closing of the vocabulary knowledge gap between EAL and FLE children over time. However, no significant difference in the growth rate of general vocabulary knowledge over time was found between the EAL and FLE children, and furthermore, while some research has found the gap in vocabulary knowledge to narrow over time (e.g., Mahon & Crutchley, 2006), significant differences are typically found to be maintained during primary school. For these reasons, it seems most likely that low statistical power resulted in the observed pattern, and that typically an achievement gap in vocabulary knowledge of some size is to be expected throughout primary school. Of course, it should be remembered that the current study was not fully longitudinal and therefore potential differences in the level of bilingualism of the two age groups make interpretation of developmental trajectories difficult; indeed, more Year 5 EAL children than Year 3 EAL children in the current study reported finding English easier to use than their L1. Finally, the fact that a significant difference emerged in Year 6 despite the small sample size might be explained by the school closures caused by the COVID-19 pandemic which occurred between T1 and T2; it is possible that the vocabulary skills of the EAL children suffered due to a sudden reduction in their exposure to English, despite participation in home-learning activities.

While the current study found an overall EAL disadvantage in vocabulary knowledge as expected, no significant difference in reading comprehension was found between the language groups. This finding was surprising, given the wealth of previous literature suggesting a clear EAL disadvantage in reading comprehension (e.g., Burgoyne et al., 2009; Hutchinson et al., 2003; Melby-Lervåg & Lervåg, 2014). While no significant differences were found, the EAL children in the current study showed lower mean reading comprehension scores than their FLE peers across all KS2 years. In addition, the overall group difference in reading comprehension was approaching significance (p = .058). For these reasons, it seems likely that no significant differences were found due to low statistical power, and that, had the sample size not been reduced by the COVID-19 closures, the EAL children would have shown a statistical weakness in reading comprehension. In addition, due to the reduced sample size, it was not feasible to conduct any analyses separately for EAL children with differing levels of vocabulary knowledge; research suggests that the disparity between EAL and FLE reading comprehension scores is larger for EAL children with low PiE (e.g., Halle et al., 2012; Kieffer, 2008), and it is therefore possible that analyses taking into account the heterogeneity of the EAL sample would have revealed weaknesses in the EAL children with lower PiE levels. It is also possible that the relatively high levels of English schooling that the EAL sample had experienced enhanced their reading comprehension abilities; the majority of the EAL sample had been attending English schools for over two years and in fact had no or minimal L1 reading experience and had therefore developed their decoding and reading comprehension skills exclusively in English. Nonetheless, the results of the current study suggest that EAL children struggle with language comprehension relative to their FLE peers to a greater extent than with reading comprehension. A further finding of the current study was that while the EAL children showed consistently lower mean reading comprehension scores than their FLE peers, the two language groups made comparable progress in reading comprehension over time. Previous literature investigating the development of reading comprehension in EAL and FLE children during primary school has often found the gap to widen somewhat over time, due to the EAL children making slower progress; encouragingly, the current study provides evidence to the contrary, suggesting that, while somewhat delayed, the developmental trajectory of reading comprehension in EAL children is comparable to that of FLE children.

7.1.2 The Predictors of Reading Comprehension in EAL and FLE Children

Overall, the results of the analyses examining the concurrent and longitudinal predictors of reading comprehension in EAL and FLE children were largely in line with predictions. Both the concurrent and longitudinal predictors of reading comprehension were found to be comparable between EAL and FLE children, due to the non-significance of language group as a predictor in the regression models tested, in line with existing literature investigating the predictors of reading comprehension in EAL and FLE children (e.g., Babayiğit, 2015; Burgoyne et al., 2011). Overall, both vocabulary knowledge and decoding ability were found to significantly predict reading comprehension, providing further support for the validity of the SVR (Gough & Tunmer, 1986) in both monolingual and language-minority learners, as previously demonstrated in the literature (e.g., Gottardo & Mueller, 2009; Verhoeven & van Leeuwe, 2012). This shows that both decoding and language comprehension are necessary for successful reading comprehension across both language groups.

Vocabulary knowledge was found to be a stronger overall predictor of reading comprehension than decoding ability was, accounting for substantial portions of variance in reading comprehension both concurrently and longitudinally. Accordingly, and in line with findings from the literature (e.g., Ouellette & Beers, 2010; Tilstra et al., 2009), the contribution of decoding ability to reading comprehension decreased with age. In fact, decoding ability was not found to be a unique longitudinal predictor of reading comprehension, further demonstrating this decline. The decreasing contribution of decoding to reading comprehension can be explained by the maturation and automatisation of decoding skills over time (e.g., Ehri, 2005). On the other hand, vocabulary knowledge remained a strong predictor of reading comprehension across KS2, emphasising the strong reliance of reading comprehension on language comprehension skills and thus the vital importance of supporting the reading development of EAL children with lower levels of PiE. In fact, the current study showed that vocabulary knowledge concurrently accounts for more unique variance in reading comprehension scores in EAL children than in FLE children. This reflects findings from the literature which suggest that language comprehension is a stronger predictor of reading comprehension in EAL children (e.g., Babayiğit, 2014; Hutchinson et al., 2003). In fact, for the EAL children alone, decoding was not found to be a significant unique predictor of reading comprehension at all; while this might be a result of reduced statistical power when dividing the sample by language group, it suggests that individual differences in decoding between EAL children are inconsequential due to a strong reliance on language comprehension.

Finally, analyses carried out for the EAL children alone showed a significant positive relationship between the amount of English use outside of school and concurrent reading comprehension outcomes. This result was expected, given the established link between English use in the home and English vocabulary knowledge in EAL learners (e.g., Gathercole & Thomas, 2009; Thordardottir, 2011). Accordingly, the results of regression analyses suggested that English use indirectly predicts reading comprehension through vocabulary knowledge. These results suggest that EAL children in England who do not frequently speak English outside of school are more at risk for disadvantage in English language comprehension and thus in reading comprehension.

Overall, the linguistic findings of the current study suggest that EAL children in England show weaknesses in English vocabulary knowledge in comparison to their FLE peers. Despite their strong decoding skills, this vocabulary deficit is likely to lead to difficulties in English reading comprehension, although no significant difference in reading comprehension were found between the language groups. In addition, English use outside of school was shown be significantly related to EAL children's English comprehension skills. While the linguistic findings of the current study reflect the existing literature to some extent, the lack of a statistically significant EAL disadvantage in reading comprehension and the relatively high bilingualism of the EAL sample demonstrate that the linguistic profiles of EAL samples from England can vary greatly and do not always follow the same pattern. In light of this, and the highly varied linguistic backgrounds and experiences of the EAL sample in the current study, research investigating the academic achievement of EAL children in England should strive to acknowledge the many nuances of bilingualism and their effects on skills associated with successful reading comprehension such as vocabulary knowledge and decoding ability. Research focusing on a subset of EAL children, such as those with lower levels of PiE, through the use of specific inclusion criteria rather than reliance on the binary classification used by schools might more readily be able to identify the key predictors of English language comprehension in EAL children and thus the groups of EAL children who are most in need of support.

7.2 Key Findings: The Mathematical Performance of EAL and FLE Children

7.2.1 EAL and FLE Differences in Mathematical Performance

The results of the analyses comparing the mathematical performance of EAL and FLE children, specifically in arithmetic ability and mathematical WPS, were partially in line with the hypotheses made. Firstly, as expected, no significant difference in composite arithmetic ability was found between the EAL and FLE children within the combined sample. This finding accords with a wealth of findings from the literature (e.g., Abedi, 2002; Trakulphadetkrai et al., 2017; Xu et al., 2021) which also report language-minority and monolingual children to have comparable arithmetic abilities. The reasons for this lie in the absence of verbal content in arithmetic calculations and the strong link between decoding skills and arithmetic ability (e.g., Hecht et al., 2001); given that the current study found the EAL children to have comparable decoding skills to their FLE peers, as hypothesised, it follows that they should have no relative difficulty with arithmetic tasks. On appraisal of the arithmetic performance of the EAL and FLE children by year group, it was found that the Year 3 and Year 4 EAL children significantly outperformed their FLE peers on the arithmetic composite, which consisted of arithmetic computation and arithmetic fluency. Whilst in opposition with the hypotheses made, this finding is not entirely surprising given the strong decoding and working memory scores shown by the Year 3 EAL children in comparison to the Year 3 FLE children and the importance of these skills to arithmetic computation (e.g., Fuchs et al., 2006). The current study also found no significant difference in the growth in arithmetic competence over time between the EAL and FLE children, as hypothesised. Overall, these results demonstrate that the arithmetic abilities of EAL children are comparable to, if not somewhat stronger than, those of their FLE peers and follow a similar developmental trajectory, suggesting that EAL status does not hinder arithmetic performance across KS2.

Contrary to expectations, no significant difference between the mathematical WPS abilities of the EAL and FLE children was found for the combined T1 sample, nor for any year group separately. This result opposes findings from the literature which have typically found language-minority children to score significantly lower than their monolingual peers on measures of mathematical WPS ability (e.g., Abedi & Lord, 2001; Trakulphadetkrai et al., 2017; Xu et al., 2021), ostensibly due to their verbal content, which places demands on reading comprehension and can lead to errors when constructing a problem model to be solved arithmetically. There are several possible reasons for this finding. Firstly, it may be that it accurately reflects the WPS abilities of EAL and FLE children of KS2 age in England, given the modest achievement gap in mathematics found in national performance data (e.g., Strand et al., 2015) and the fact that this narrows with age. Overall, the EAL children in the current study did show somewhat lower mean scores in WPS than their FLE peers despite the difference being non-significant; given the heterogeneity of the EAL sample and that of the overall EAL population in England, this result is not entirely surprising. It is possible that greater disparities in WPS would have emerged for the EAL children with lower levels of PiE, in line with findings to this effect from Halle and colleagues (2012), had it been feasible to analyse the data in this way. It is also possible that the non-significant differences in WPS scores were a result of the unusual patterns of linguistic and arithmetic ability found in the current sample; the comparable reading comprehension scores of the language groups and the strong arithmetic skills of the younger EAL children relative to their FLE peers might have resulted in an EAL group with stronger WPS abilities than typically found in other studies. Finally, methodological issues primarily related to the nature of the bespoke WPS tasks used in the current study, detailed in Section 5.4, might have led to misrepresentations of the WPS abilities of the sample. An additional finding of the current study was that the EAL children were found to make significantly faster progress in WPS ability over time than their FLE peers. While this might reflect their growth in language comprehension over time and, accordingly, a narrowing of the achievement gap, this result likely also reflects the fact that the younger FLE children made very little progress in WPS between T1 and T2. Given the school closures that occurred between T1 and T2, it is difficult to interpret this result meaningfully without further investigation.

Although the arithmetic and mathematical WPS abilities of the EAL and FLE children were found to be comparable overall, the Year 3 EAL children showed a significantly greater disparity between scores on the bespoke parallel tasks measuring arithmetic computation and WPS than their FLE peers. In line with predictions, this finding shows that the contextualisation of arithmetic problems into mathematical word problems can result in a greater reduction in performance for EAL children than for FLE children, even when their arithmetic ability is strong. This finding accords with evidence from the literature which demonstrates that mathematical word problems exhibit DIF for

EAL and FLE children despite their comparable arithmetic skills (e.g., Martiniello, 2008). In light of the comparable WPS scores of the EAL and FLE children in the current sample, it is perhaps surprising that this result emerged. This highlights the benefit of administering parallel tasks which are able to reveal the direct result of contextualisation in EAL and FLE children in the absence of any other differences in scores between the tasks. This result demonstrates that although EAL status may appear to have minimal effect on mathematical performance when comparing EAL and FLE children cross-sectionally, EAL children with low language comprehension skills might indeed experience difficulties with tests of mathematical ability which are high in verbal content, and this could lead to the misrepresentation of their mathematical abilities.

7.2.2 The Predictors of Mathematical Performance in EAL and FLE Children

Overall, the concurrent and longitudinal predictors of both arithmetic computation and mathematical WPS were not found to differ for the EAL and FLE children, in line with the hypotheses made, as well as evidence from the literature (e.g., Foster et al., 2018; Spencer et al., 2020; Xu et al., 2021). This demonstrates that the skills necessary for successful arithmetic computation and WPS are the same regardless of language status. Considering first the academic predictors of mathematical ability, both reading comprehension and arithmetic fluency were found to uniquely predict arithmetic computation concurrently across both language groups. Of the two, however, only arithmetic fluency was found to be a unique longitudinal predictor of arithmetic computation. While it was expected that arithmetic fluency would be the only unique predictor, the concurrent role of reading comprehension is not surprising given the importance of phonological decoding to both reading comprehension (e.g., Hoover & Gough, 1990) and arithmetic computation (e.g., Hecht et al., 2001). As hypothesised, and in line with the dual representation model of mathematical WPS (Kintsch & Greeno, 1985) as well as recent research (e.g., Lin, 2021), reading comprehension and arithmetic fluency were both found to predict WPS concurrently and longitudinally across both language groups. This suggests that reading comprehension is a more robust predictor of WPS than of arithmetic computation, which is not surprising given the importance of correctly comprehending the verbal content of mathematical word problems. In addition, reading comprehension was found to be a marginally stronger predictor of WPS for the EAL children than for the FLE children, suggesting that the WPS abilities of EAL children are more limited by reading comprehension weaknesses than those of FLE children are.

The cognitive and linguistic predictors of arithmetic computation were found to be decoding ability and mathematical vocabulary knowledge in both language groups, both concurrently and longitudinally. While the role of decoding in arithmetic computation is in line with evidence from the literature (e.g., Hecht et al., 2001), mathematical vocabulary knowledge was not expected to contribute uniquely to arithmetic computation given the lack of verbal content in the computation task. As suggested previously, it is possible that mathematical vocabulary knowledge acted as a proxy for overall mathematical ability given the lack of such a predictor in the model. In accordance with the hypotheses and existing research investigating the predictors of mathematical WPS (e.g., Fuchs et al., 2006; Lin, 2021), decoding and general vocabulary knowledge were found to uniquely predict concurrent mathematical WPS ability. The fact that general language comprehension skills were found to be predictive of concurrent WPS ability, but not arithmetic computation, accords with findings from the literature (e.g., Fuchs et al., 2006) and highlights mathematical WPS as a particularly challenging area of mathematics for EAL children. Indeed, general vocabulary knowledge was found to be a stronger predictor of mathematical WPS for the EAL children than for the FLE children, in line with evidence from Xu and colleagues (2021), further emphasising the vital importance of language comprehension to mathematical WPS in EAL children. Interestingly, while decoding ability was found to be a unique longitudinal predictor of WPS, general vocabulary knowledge was not, despite a strong longitudinal correlation between the general vocabulary knowledge and WPS. This was perhaps due to an overlap with mathematical vocabulary knowledge which was also included in the model, or due to the reduction in sample size when considering the T2 data.

Finally, an additional finding of the current study was that mathematical vocabulary knowledge did not significantly predict mathematical WPS concurrently nor longitudinally, over the contribution of general vocabulary knowledge. Previous research on the topic is scarce and has shown mixed results, often finding mathematical vocabulary knowledge to uniquely predict WPS in monolingual samples but not in language-minority samples (e.g., Peng & Lin, 2019; Xu et al., 2021), ostensibly due to the overwhelming influence of general vocabulary knowledge to WPS in language-minority learners. The current study did not find mathematical vocabulary knowledge to uniquely contribute to WPS in either language group beyond the contribution of general vocabulary knowledge, though a stronger correlation between mathematical vocabulary knowledge and WPS was found for the FLE children than for the EAL children. Given the relatively low internal reliability scores of the bespoke mathematical vocabulary knowledge measures created for the current study, it is unclear whether these results accurately reflect the relationship between mathematical vocabulary knowledge and WPS in KS2 children; further research using more stringently developed measures is warranted.

7.3 Strengths and Limitations

One notable strength of the study presented in this thesis is its cross-sequential design. This allowed for both cross-sectional and longitudinal analysis to be conducted, and for data to be collected from children in all KS2 years within a suitable timeframe for the project. Few studies exist which have analysed the academic performance of EAL and FLE children, particularly within the UK context, across a number of years and specifically throughout the course of KS2, meaning that the current study is one of the first to do so. While interpretation of the developmental trajectories of the sample was slightly limited because the design was not fully longitudinal, due to two different groups of children being represented across KS2, a cross-sequential design was selected as a favourable alternative given the time constraints of the current project. The current study also added to the limited existing research investigating the mathematical performance of EAL and FLE children in relation to their linguistic abilities. In particular, very little research exists which compares the concurrent or longitudinal predictors of arithmetic computation and mathematical WPS between EAL and FLE children, and, furthermore, the majority of the existing research was carried out in the USA. Therefore, the current study is unique in its comparison of the mathematical abilities as well as the concurrent and longitudinal predictors of mathematical ability between EAL and FLE children within the UK context and across the course of KS2.

A further strength of the current study lies in its creation and use of parallel mathematical tasks which contain the same calculations presented as arithmetic problems and as mathematical word problems. The use of these tasks allowed the effect of contextualising arithmetic calculations into word problems to be directly measured for the EAL and FLE children through comparison of their performance on the two tasks. While this approach has been used in studies assessing monolingual samples (e.g., Bjork & Bowyer-Crane, 2013), the current study is among the first to use such measures to examine the mathematical abilities of EAL children. In addition, the current study included a measure of mathematical vocabulary knowledge in its test battery; the mathematical vocabulary knowledge of EAL and FLE children and its relationship with performance on different mathematical tasks has not been widely researched, and the current study adds constructively to this small body of research. A final strength of the study is that all bespoke measures were piloted prior to use in the main study and modified based on the results of item analysis, ensuring their quality.

Despite the discussed strengths, the current study has a number of limitations which should be considered when interpreting the present findings. Firstly, the COVID-19 pandemic resulted in two periods of school closures which, while requisite and beyond the researcher's control, altered and limited both the analysis and interpretation of the data collected. The first period of school closures began during T1 data collection and resulted in a loss of 19 recruited participants. This meant that the T1 sample was considerably smaller than planned, resulting in the analyses having reduced statistical power; for example, the difference in reading comprehension scores between the EAL and FLE children was marginally non-significant ($p = .058$) and would likely have been significant had all recruited children been able to participate. In addition, 13 of the 19 lost participants were EAL learners, resulting in uneven group sizes. Given that the T1 sample was reduced, a decision was made to combine the year groups and conduct all initial analyses on the combined sample. Because of this, and in order to allow comparison of scores on the bespoke measures which were designed separately for the year groups, 15 points were added to the scores of the older children on the bespoke measures, to represent hypothetical correct answers on the measures designed for the younger children. However, this may have misrepresented the abilities of the Year 5 children, particularly those of the EAL children whose comprehension skills might have hindered their performance even on the simpler tasks. Due to the sudden school closures, 16 children were only able to complete one T1 data collection session, resulting in missing data for these children; this data was therefore replaced using multiple imputation. While the use of multiple imputation to alleviate the repercussions of the unexpected school closures can be considered a strength of the current study, given that multiple imputation makes use of all available data and generates unbiased estimates, the imputed data points are nevertheless estimates and might not have accurately captured the abilities of the corresponding participants.

The longitudinal analyses in the current study were also limited by the COVID-19 school closures. Firstly, a second period of school closures starting in January 2021 resulted in a substantial loss of participants at T2. Again, this resulted in the year groups being combined for initial analyses and reduced statistical power. In addition, the longitudinal analyses were limited to the children who participated at both time points and therefore could not make use of the full T1 dataset. Furthermore, the first school closures which occurred between T1 and T2 made interpretation of the longitudinal data difficult, given the sudden switch to home learning for the majority of participants and the resulting irregularity of their educational experience in comparison to that of typical cohorts in previous studies. While an attempt was made to assess each child's home learning experiences through a questionnaire, the data generated through these questionnaires was rudimentary and was gathered from the children themselves, resulting in doubt regarding its reliability. While the data collected indicated no significant difference in the home learning experiences of the EAL and FLE children and no relationship between the frequency of home learning participation and academic development, it is unclear whether these findings are accurate and reliable, and how the T2 sample might have performed academically had the school closures not occurred.

Secondly, irrespective of the reduction in sample size caused by the COVID-19 pandemic, the sample size of the current study was relatively small due to difficulties with recruitment, and this limited the analyses which could be performed. For example, it was not feasible to split the EAL sample by factors such as PiE or the age at which the EAL children joined schools in England, meaning that the heterogeneity of the EAL population in England could not be fully accounted for. While the EAL sample does reflect the EAL population in England in terms of its heterogeneity, the comparisons made between the EAL and FLE children were very broad in scope and did not account for individual differences within the EAL group. Given that the EAL children who participated in the current study spoke a total of 12 different L1s, it was also not feasible to perform any analyses separately for speakers of different languages. Furthermore, given the small sample size, it was necessary to create composite variables in order to reduce the number of variables entered into the analyses; for this reason, it was not possible to examine or account for the contributions of some skills individually, such as working memory and speed of lexical access.

Thirdly, while questionnaires were sent to parents regarding the language backgrounds and home learning experiences of their children, only approximately one in three parent questionnaires were returned. As previously mentioned, this meant that data was generated solely from the child versions of these questionnaires, casting doubt regarding the reliability of the resulting data. It is possible that some parents of the EAL children were not able to complete the questionnaires due to low PiE, given that the questionnaires were only distributed in English. This was also true for the consent forms and information sheets sent out to parents during the recruitment phase of the study. Given the wide range of languages spoken by EAL children in England and indeed by the eventual current EAL cohort, it was not feasible to create translated versions of these materials within the constraints of the current project; this may have led to sampling bias given that some parents with low PiE may have been unable to make an informed decision about their child's participation. Indeed, there is evidence that language proficiency is linked to survey response rate in bilingual populations (Kappelhof, 2013). Thus, it is possible that many of the EAL children who participated in the current study came from homes in which English is spoken or understood, and that the eventual EAL sample might have possessed somewhat higher levels of PiE on average than a sample which was fully representative of the EAL population in England might have.

Finally, the current study has several limitations regarding the choice of measures included in the test battery. Firstly, due to the large battery of linguistic measures required, the number of mathematical measures which could be included was limited. However, the inclusion of a standardised measure of mathematical WPS would have been beneficial in order to assess the validity of the bespoke measure created by the researcher. In addition, separate versions of the bespoke mathematical measures were created for the Year 3 and Year 5 children; given the longitudinal nature of the study and the eventual need to combine the year groups due to the reduction in sample size, it would have been beneficial to instead create one task for each ability which encompassed the abilities of both Year 3 and Year 5 children. Secondly, while the linguistic battery of tests was large, no measures of grammatical knowledge or listening comprehension were included. Given that these are considered to be key components of language comprehension (e.g., Hoover & Gough, 1990; Muter et al., 2004), their inclusion would have allowed a more rounded assessment of language comprehension. Thirdly, the L1 linguistic and mathematical abilities of the EAL children were not assessed, despite evidence of cross-language transfer between languages which might affect L2 linguistic development (e.g., Melby-Lervåg & Lervåg, 2011). While the wide range of L1s spoken by the current EAL cohort made this unfeasible, research conducted with EAL children should strive to capture a holistic view of their linguistic abilities and to place the same value on L1 abilities as on L2 abilities. Finally, the standardised measures used in the current study had not been normed with EAL samples. As well as necessitating the use of raw scores in all analyses, this means it is unclear how culturally applicable the measures used are to EAL children. This is a particularly important consideration for measures of comprehension skills; cultural background knowledge has been found to be important for successful reading comprehension (e.g., Johnson, 1981) and thus it is unclear whether the YARC was able to accurately capture the reading comprehension skills of both the EAL and FLE children.

7.4 Future Directions

Taking into consideration the discussed strengths and limitations of the current study, a number of possible directions for future research are recommended. Firstly, in light of the repercussions of the COVID-19 pandemic on the current study, future research should strive to replicate the current study using a larger sample size. This would increase the statistical power of the analyses, allowing all analyses to be conducted reliably for the language groups, as well as for the year groups separately, as originally intended. In particular, it would allow stronger conclusions to be drawn regarding the mathematical performance of EAL and FLE children and its relationship with their linguistic abilities, given that this is an area of research which is critically under-researched, particularly in the UK context. A larger sample size would also allow the contributions of additional predictors, such as working memory, to be accounted for. Furthermore, research with consistent sample sizes at both T1 and T2 would allow stronger conclusions to be drawn regarding the developmental trajectories of the linguistic and mathematical abilities of EAL and FLE children.

Future research carried out with a larger sample would also enable individual differences within the EAL sample to be accounted for more extensively. For example, future research should consider the PiE levels of the EAL sample, comparing the academic performance of EAL children with differing levels of PiE to their FLE peers in order to facilitate identification of the EAL children who are most in need of support. In addition, future research should strive to consider the home language environments of its participating EAL children and their relationship with academic outcomes to a greater extent. While the current study relied on information from the children themselves regarding their home language environment, future research should ensure that this information can be collected from their parents or caregivers, or perhaps even conduct observations in order to gain a clear understanding of each child's exposure to, and use of, each of their languages at home.

In light of the hitherto small body of research investigating the mathematical vocabulary knowledge of EAL and FLE children and its contribution to mathematical performance, particularly in the UK context, future research should aim to investigate this more closely. Given that mathematical vocabulary is learned primarily within the school context, EAL children could readily be given extra support in developing mathematical vocabulary knowledge should it prove to contribute positively to their mathematical performance. In order to facilitate such research, the creation of a rigorously designed measure of mathematical vocabulary knowledge suitable to the UK context would be beneficial.

Finally, future research should aim to assess the impact of the school closures caused by the COVID-19 pandemic on the academic performance of EAL children in comparison to their FLE peers. While the current study gathered rudimentary data on the home learning experiences of the sample, it was not possible to compare their academic performance following the school closures to that of a typical pre-pandemic cohort. Given that research suggests that the English vocabulary skills of EAL children are disproportionately affected by prolonged periods with no formal schooling (e.g., Lawrence, 2012), it is possible that EAL children experienced greater setbacks than FLE children in vocabulary knowledge, which in turn might have disproportionately affected their academic performance given the importance of language comprehension to academic outcomes in EAL children. For this reason, it is vital to determine the impact of the school closures on the educational outcomes of EAL children, in order to provide additional support to those affected.

7.5 Educational Implications

The findings presented in this thesis have several practical applications for educational practice and policy. Firstly, the findings are useful in helping educators to identify the areas in which their EAL students would benefit from additional support. The current research has demonstrated that EAL children in England have significantly weaker general vocabulary knowledge than their FLE peers, and that this is likely to in turn hinder their reading comprehension abilities. Given that reading comprehension is a vital academic skill, schools and educators should strive to target and support the vocabulary skills of their EAL students in order to ensure that they do not fall behind academically and are able to make the most of their educational experience; there is evidence that interventions targeting vocabulary knowledge in EAL children in the UK context can be successful in improving vocabulary outcomes. For example, a vocabulary intervention by Dixon, Thomson and Fricke (2020) resulted in significant EAL gains in knowledge of a set of targeted Tier-2 words, which were maintained six months later. This intervention consisted of 10 weekly 25-minute sessions which involved discussion of the definitions of the target words and incorporated them into word games, sentence completion and construction tasks, and passage reading. While the current study demonstrated the importance of vocabulary knowledge in EAL reading comprehension and academic achievement, the current study demonstrated that EAL children are conversely not in need of additional support in phonics, given that the EAL and FLE children in the current study were found to have comparable decoding skills.

Importantly, the findings presented in this thesis also demonstrate the strong contribution of language skills to mathematical performance in EAL and FLE children, highlighting the importance of providing additional support to EAL children in mathematics as well as literacy. In particular, the findings have shown that vocabulary knowledge and reading comprehension, in which EAL children typically show weaknesses, are particularly vital to the successful completion of mathematical tasks which have linguistic content such as mathematical WPS tasks. This suggests that targeting vocabulary knowledge in interventions could also have a positive effect on the mathematical outcomes of EAL children; this should be investigated in future research. Conversely, the current study showed that EAL children do not struggle with mathematical vocabulary knowledge in comparison to FLE children and that mathematical vocabulary knowledge does not predict their WPS performance; this suggests that EAL children do not need additional support in mathematical vocabulary knowledge and emphasises that general vocabulary knowledge should be targeted to improve EAL mathematical outcomes. In addition, based on the fact that no significant difference was found between the language groups in terms of arithmetic ability, EAL children as a group also do not require additional arithmetic support.

Based on the discussed results of the current study, schools should aim to provide targeted vocabulary and reading comprehension support for their EAL children. In particular, language difficulties seem to be greater in younger EAL children and decrease over time, so support should begin early in order to minimise the trajectory of their influence. Previous research has found that individual or small-group support outside of class is effective in scaffolding academic achievement in EAL children (e.g. Strand et al., 2010); this could take the form of weekly sessions targeting vocabulary, following the structure of successful interventions such as that of Dixon and colleagues (2020). Strand and colleagues (2010) also reported that dedicated group or 1-1 support in class was effective in increasing academic achievement in EAL children, as were regular reviews by the school of the educational needs of each EAL child; these practices are therefore recommended to schools. Reviewing the needs of EAL children regularly is particularly important in the aftermath of the COVID-19 pandemic; it is possible that the gap in formal education during the pandemic increased the support needs of some EAL children. In addition, schools with EAL pupils should encourage their classroom teachers to employ strategies recommended for the teaching of EAL children, such as revoicing and code-switching (e.g., Suh, 2020), in both literacy and mathematics lessons to aid their EAL students' understanding of new concepts. Research has suggested that teachers of EAL children in the UK are often unaware of how they can make use of the linguistic and cultural diversity of their classrooms within their lessons; schools should aim to provide training for their teachers to this end.

Strand and colleagues (2010) also recommend that schools should strive to acknowledge and celebrate the backgrounds of their EAL pupils outside of class in order to boost their academic performance. For example, events celebrating diversity and showcasing different cultures and after-school clubs are effective in engaging EAL children more in school, and schools should also aim to increase parent engagement through induction sessions with parents of EAL children and through ensuring regular and tailored communication with parents of EAL children who might have little knowledge of the education system in England or limited PiE. The importance of effective communication between schools and the parents of EAL children has also been demonstrated in a recent systematic review focusing on home-school partnerships for EAL children in the UK and Ireland (Stewart, Skinner, Hou & Kelly, 2022); the authors recommend practices such as provision of translation services, a key contact in the school for each family, identifying the educational support needs of the parents of EAL children and familiarising them with the education system. Finally, given the link between English use outside of school and essential abilities such as reading comprehension, and the fact that EAL children might have limited exposure to English in the home or receive limited support with homework due to low parental PiE, schools might suggest to parents that they enrol their children in homework clubs or other supplementary education in order to boost their children's academic performance. Overall, schools should ensure that they provide effective dedicated support for their EAL pupils, particularly in the areas of vocabulary knowledge and reading comprehension, and strive to facilitate parent-school engagement through tailored and regular communication with parents of EAL children.

Additionally, the current study demonstrated that educators should exercise caution when assessing the mathematical abilities of EAL children through mathematical word problems, given that the contextualisation of arithmetic calculations into word problems causes a significantly greater reduction in performance for EAL children than for FLE children and can therefore misrepresent their mathematical abilities. Educators should consider this when preparing EAL children for mathematical assessments and, accordingly, provide them with targeted support to aid them in the successful comprehension of mathematical word problems. This could take the form of methods suggested above, such as 1-1 or group sessions outside of class. Schools might also consider providing accommodations for EAL children when sitting mathematical tests with high language content, such as simplifying the language used in the test, providing bilingual glossaries or reading the questions aloud to the children.

Finally, the sample of EAL children investigated in the current study was highly heterogeneous, with the sample showing wide variation in factors such as English linguistic ability and the use of English outside of school. In light of this, schools and educators should refrain from relying solely on the binary classification of EAL status, as defined by the DfE, when allocating additional support for EAL children. In order to allow schools and indeed researchers to identify the EAL children most at risk for disadvantage more easily, it is recommended that the requirement for schools to assess the PiE levels of their EAL students should be reinstated. Given that binary classification based on the DfE definition of EAL status is likely to misrepresent many EAL children's academic performance, and that educational outcomes in EAL children are strongly related to PiE (e.g., Strand & Hessel, 2018), this would likely help to provide a clear indication of which students are most in need of support. Indeed, educators are advised that it would be prudent to assess the PiE levels of their EAL students despite the current lack of obligation, in order to be able to provide support more readily and efficiently to the EAL children who are most at risk of disadvantage.

7.6 Final Conclusion

In conclusion, the work presented in this thesis adds constructively to the small but growing body of research investigating the link between linguistic ability and mathematical performance in EAL children in the UK. In particular, the findings of the current study confirm that EAL children in England typically show weaker vocabulary skills than their FLE peers, and that this disadvantage can lead to difficulties with reading comprehension as well as with mathematics. In particular, comprehension skills were shown to be strong predictors of mathematical WPS in EAL children, and the current study demonstrated that the robust arithmetic abilities of EAL children can be misrepresented when their mathematical competence is assessed through mathematical WPS tasks. The current study also highlighted the heterogeneity of the EAL population in the UK and the resulting importance of identifying, and directing additional support to, the EAL learners who are most in need of support. Drawing together these findings, educators should endeavour to acknowledge the nuances of the EAL population in the UK and to target the comprehension skills of their EAL students who are most at risk for disadvantage, in order to effectively support their linguistic and mathematical development throughout primary school and beyond.

Appendix 1: School Information Sheet and Consent Form

UNIVERSITY of York

DEPARTMENT OF EDUCATION

Heslington, York, YO10 5DD

Web: www.york.ac.uk/educ

10/02/2019

Information Sheet

Investigating the relationship between language and mathematics skills in children learning English as an Additional Language in the UK.

Dear Sir/Madam,

I (Evie Smith) am a PhD student at the University of York and am currently carrying out a research project investigating the relationship between language and mathematics skills in children learning English as an Additional Language in the UK'. I would like to invite your school to take part in this research project.

Before agreeing to take part, please read this information sheet carefully and let me know if anything is unclear or you would like further information. For information about General Data Protection Regulation (GDPR) please read the attached document.

Purpose of the study

The study is designed to investigate whether there are differences between children who speak English as an Additional Language (EAL children) and their monolingual peers in terms of language, literacy and maths skills. It will also look at how language, literacy and maths skills are related to each other. The study will assess both EAL children and children whose first language is English to assess any differences in achievement between the two groups, and will involve re-testing each child after one year to assess the changes in their language, literacy and maths abilities over time.

What would this mean for your school?

Participating children in your school would be asked to complete a series of paper-based tasks appropriate to their age measuring language skills such as vocabulary knowledge and reading comprehension, mathematics skills involving word problems and arithmetic problems, and also memory. These tasks would be split over two sessions with each child, each lasting approximately 40 minutes. Parts of the sessions would be audio recorded. The study would take place in your school during teaching hours, in the autumn or spring term of 2019/20 and again in the autumn or spring term of 2020/21, meaning the participating children would complete the two sessions once this academic year and once next academic year. Your school might also be asked to provide demographic information on each participating child (for example their date of birth and whether they are in receipt of free school meals) on receipt of parental consent.

Participation is voluntary

Participation is optional. If you do decide that your school will take part, you are asked to keep this information sheet for your records. Informed parental consent will be required for each child to take part, and without this, children will not be able to take part. Each child will be asked to give verbal assent to take part in the study at the start of each session and without their agreement the session will not go ahead. If you change your mind at any point during the study, you will be able to withdraw your school's participation without having to provide a reason. Each child can also withdraw from the study at any point without having to provide a reason.

Anonymity and confidentiality

The data that the children in your school provide (i.e. test and questionnaire results) will be stored anonymously by code number. Any information that identifies the children or your school will be stored separately from the data. Your school is free to withdraw from the study at any time during data collection and up to 3 weeks after the final visit.

Information will be treated confidentially and shared on a need-to-know basis only. The University is committed to the principle of data protection by design and default and will collect the minimum amount of data necessary for the project. In addition, we will anonymise or pseudonymise data wherever possible.

Storing and using your school's data

We will put in place appropriate technical and organisational measures to protect your school's personal data. Data will be stored in secure filing cabinets and on a password protected computer. I am practising Open Science and anonymised data will be managed professionally and stored indefinitely with the University's Research Data York service.

The data that I collect (test and questionnaire responses) may be used in *anonymous* format in different ways. Please tick on the consent form enclosed if you are happy for this anonymised data to be used in the ways listed.
Please note: If information is gathered that raises concerns about any child's safety or the safety of others, or about other concerns as perceived by the researcher, the researcher may pass on this information to another person.

Sharing of data

Data will be accessible to myself and my supervisor only.
Anonymised data may be used for future analysis and shared for research or training purposes. If you do not want your school's data to be included in any information shared as a result of this research, please do not sign the consent form.

Questions or concerns

If you have any questions about this participant information sheet or concerns about how your school's data will be processed, please feel free to contact Evie Smith by email (ecs515@york.ac.uk) or the Chair of Ethics Committee via email at education-research-administrator@york.ac.uk.

I hope that you will agree to your school taking part. You will only be required to complete the consent form on the following page should you decide as such, and this will be done during a face-to-face meeting if possible. Please keep this information sheet for your own records. Thank you for taking the time to read this information.

Yours sincerely,
Evie Smith

Consent Form

Please tick each box if you are happy for your school to take part in this research.

I confirm that I have read and understood the information given to me about the above named research project and I understand that this will involve my school taking part as described above.

I understand that the purpose of the research is to investigate the differences between children who speak English as an Additional Language (EAL) and monolingual children in terms of language skills, literacy skills and maths skills.

I understand that participation in this study is voluntary.

I understand that data will be stored securely in a secure filing cabinet and on a password protected computer.

I understand that my school's data will not be identifiable and the data may be used:

in publications that are mainly read by university academics

in presentations that are mainly attended by university academics

in publications that are mainly read by the public

in presentations that are mainly attended by the public

freely available online

I understand that my school's anonymised data can be stored indefinitely and used in the future for research purposes.

I understand that I can withdraw my school's data at any point during data collection and up to 3 weeks after data is collected.

I understand that any information that identifies the children or the school will only be accessed by Evie Smith, and will be kept until the withdrawal period has passed, after which it will be destroyed.

NAME_____________________________

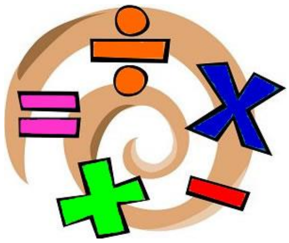
SIGNATURE________________________________

DATE________________________

Appendix 2: Parent Information Sheets and Consent Form

Dear Parent/Guardian,

Your child's school has decided to participate in a research study I am running as part of my PhD at the University of York, and I would like to invite your child to take part. The study will look at the links between language skills and maths skills in children with English as an additional language and children whose first language is English.



This invitation is being sent to the parents/guardians of all current Year 3 and Year 5 children. If your child is selected to take part, the study would involve two sessions with your child each lasting roughly 40 minutes, in school during teaching hours. These sessions would then be carried out again next year if possible. The sessions would be 1:1, and would involve your child completing a range of age-appropriate tasks measuring their language skills, maths skills and memory. Parts of these sessions will be audio-recorded so they can be analysed afterwards, however I will be the only person with access to these recordings and they will be destroyed once they are no longer needed.

Your child's data will be anonymised and stored securely. Any identifying information will be stored separately and destroyed after the project is completed. Please read the information sheet provided for further details. If you have any questions, or would like further details about General Data Protection Regulation (GDPR), please contact me at ecs515@york.ac.uk . If you are happy for your child to take part, please complete the consent form. You may also be asked to provide some information on your child's language background at a later date.

If you are willing for your child to take part, please return the completed consent form to school as soon as possible.

Many thanks,

Evie Smith (PhD student, University of York)

Investigating the relationships between language and mathematics skills in children learning English as an Additional Language in the UK.

Consent Form

Please tick each box if you are happy for your child to take part in this research.

I confirm that I have read and understood the information given to me about the above named research project and I understand that this will involve my child taking part as described above.

I understand that the purpose of the research is to investigate whether there are differences between children who speak English as an Additional Language (EAL) and monolingual children in terms of language skills and maths skills.

I understand that participation in this study is voluntary.

I understand that data will be stored securely in a secure filing cabinet and on a password protected computer.

I understand that my child's data will not be identifiable and the data may be used:

in publications that are mainly read by university academics

in presentations that are mainly attended by university academics

in publications that are mainly read by the public

in presentations that are mainly attended by the public

freely available online

I understand that my child's anonymised data can be stored indefinitely and used in the future for research purposes.

I understand that I can withdraw my child's data at any point during data collection and up to 3 weeks after data is collected.

I understand that any information that identifies my child will only be accessed by Evie Smith, and will be kept until the withdrawal period has passed, after which it will be destroyed.

Do you consent to your child being audio recorded? YES NO

NAME_____________________________ SIGNATURE________________________________

DATE________________________

Please also fill in the following information:

Your child's name: ____________________________ Your child's date of birth: ___________

Your child's gender: ___________________________ Your child's school year: ☐ Year 3

☐ Year 5

Is your child growing up with more than one language? YES NO

Is your child currently in receipt of Free School Meals? YES NO

Does your child have any Special Educational Needs? YES NO

If YES, please specify:_________________________________

UNIVERSITY of York

DEPARTMENT OF EDUCATION

Heslington, York, YO10 5DD

Web: www.york.ac.uk/educ

06/09/2019

Information Sheet

Investigating the relationship between language and mathematics skills in children learning English as an Additional Language in the UK.

Dear Parent,

I (Evie Smith) am a PhD student at the University of York and am currently carrying out a research project investigating the relationship between language and mathematics skills in children learning English as an Additional Language in the UK'. I would like to invite your child to take part in this research project.

Before agreeing to take part, please read this information sheet carefully and let me know if anything is unclear or you would like further information. If you would like any details about General Data Protection Regulation (GDPR) please contact me at ecs515@york.ac.uk.

Purpose of the study
The study is designed to investigate whether there are differences between children who speak English as an Additional Language (EAL children) and their monolingual peers in terms of language and maths skills. It will also look at how language and maths skills are related to each other. The study will assess both EAL children and children whose first language is English, and will involve re-testing each child after one year if possible to assess the changes in their language and maths abilities over time.

What would this mean for your child?
Your child will be asked to complete a series of paper-based tasks appropriate to their age measuring language skills such as vocabulary knowledge and reading comprehension, mathematics skills involving word problems and arithmetic problems, and also memory. These tasks will be split over two sessions with each child, each lasting approximately 40 minutes. Parts of the sessions will be audio recorded. The study will take place in your child's school during school hours, in the spring term of 2020 and again in the spring term of 2021 if possible. If you agree for your child to take part, you be required to provide demographic information on your child (for example their date of birth and whether they are in receipt of free school meals).

Participation is voluntary
Participation is optional. If you do decide that your child will take part, you are asked to keep this information sheet for your records. Your child will be asked if they want to take part in the study at the start of each session, and can say no without having to provide a

reason. If you change your mind at any point during the study, you will be able to withdraw your child's participation without having to provide a reason. Your child can also withdraw from the study at any point without having to provide a reason.

Anonymity and confidentiality
The data that your child provides (i.e. test and questionnaire results) will be stored anonymously by code number. Any information that identifies your child will be stored separately from the data. You and your child are free to withdraw from the study at any time during data collection and up to 3 weeks after the final visit. Information will be treated confidentially and shared on a need-to-know basis only. The University is committed to the principle of data protection by design and default and will collect the minimum amount of data necessary for the project. In addition we will anonymise or pseudonymise data wherever possible.

Storing and using your child's data
We will put in place appropriate technical and organisational measures to protect your child's personal data. Data will be stored in secure filing cabinets and on a password protected computer. I am practising Open Science and anonymised data will be managed professionally and stored indefinitely with the University's Research Data York service. The data that I collect (test and questionnaire responses) may be used in *anonymous* format in different ways. Please tick on the consent form enclosed if you are happy for this anonymised data to be used in the ways listed.

Please note: If information is gathered that raises concerns about your child's safety or the safety of others, or about other concerns as perceived by the researcher, the researcher may pass on this information to another person.

Sharing of data
Data will be accessible to myself and my supervisor only.
Anonymised data may be used for future analysis and shared for research or training purposes. If you do not want your child's data to be included in any information shared as a result of this research, please do not sign the consent form.

Questions or concerns
If you have any questions about this participant information sheet or concerns about how your child's data is will be processed, please feel free to contact Evie Smith by email (ecs515@york.ac.uk) or the Chair of Ethics Committee via email at education-research-administrator@york.ac.uk.

I hope that you will agree to your child taking part. If you are happy for your child to participate, please complete the form enclosed and return to your child's school as soon as possible. Please keep this information sheet for your own records. Thank you for taking the time to read this information.

Yours sincerely,

Evie Smith

Appendix 3: Parent Language Questionnaire

UNIVERSITY of York

DEPARTMENT OF EDUCATION Heslington, York, YO10 5DD

Web: www.york.ac.uk/educ

Email: ecs515@york.ac.uk

Parent/Guardian Questionnaire

This questionnaire is part of the research on the relationship between language and maths in EAL children being carried out by Evie Smith from The University of York.

- This information will only be used to investigate the project data
- Children's names will be replaced by letter/number codes.

Please answer the questions below.

This questionnaire is for parents of Year 3 and Year 5 children who are growing up with more than one language – if this does not apply, please disregard this questionnaire.

Your child's name: ___________________________

Is your child growing up with more than one language? ☐ Yes ☐ No

1. What level of SPOKEN English do you and your partner (if applicable) have?

	Beginner	Low-intermediate	Intermediate	High-intermediate	Native-like	Native
You						
Your partner (if applicable)						

2. What level of WRITTEN English do <u>you and your partner</u> (if applicable) have?

	Beginner	Low-intermediate	Intermediate	High-intermediate	Native-like	Native
You						
Your partner (if applicable)						

3. What is <u>your</u> first language/mother tongue? [Please complete for <u>all parents/guardians</u>]

Parent/Guardian 1 ___________________ Parent/Guardian 2 __________________

4. Was your child born in the UK?

Yes	No

If NO: Where was your child born? ____________________________________

If NO: At what age did your child move to the UK? ____________________________

5. Which language or languages does <u>your child</u> UNDERSTAND <u>in addition to English</u>?

1.	2.	3.

6. Which language or languages can <u>your child</u> SPEAK <u>in addition to English</u>?

1.	2.	3.

7. Which language or languages can <u>your child</u> READ <u>in addition to English</u>?

1.	2.	3.

8. In which language or languages can <u>your child</u> WRITE <u>in addition to English</u>?

1.	2.	3.

9. Did your child attend an English speaking nursery/preschool/childminder?

Yes	No

If YES, how many days per week? ____________________

10. Which language(s) does your child HEAR, and from whom?

	Only English	**Mostly English**, but sometimes another language	**Both** English and another language equally	**Mostly not English**, but sometimes another language	**Only non-English**
Parents/Guardians					
Brothers/Sisters					
Other family members					
Friends					

11. Which language(s) does your child SPEAK, and with whom?

	Only English	**Mostly English**, but sometimes another language	**Both** English and another language equally	**Mostly not English**, but sometimes another language	**Only non-English**
Parents/Guardians					
Brothers/Sisters					
Other family members					
Friends					

12. When at home, which language(s) does your child use in these situations? In which language does your child read or watch TV/films?

	Only English	**Mostly English**, but sometimes another language	**Both** English and another language equally	**Mostly not English**, but sometimes another language	**Only non-English**

General conversation					
When doing maths					
When playing on their own					
When reading books or magazines					
When watching TV or films					

If you wish, you may add any additional comments about the languages your child hears and speaks:

Thank you very much for completing this questionnaire. Please return it to your child's school as soon as possible.

Appendix 4: Child Language Questionnaire

Child Language Questionnaire

1. What language(s) can you understand other than English? ___________________________________

____

2. Can you speak in that language? ____

(If yes to 2) Do you find it easier to speak in English or your L1? ____________________

3. Can you read in that language? ____

(If yes to 3) Do you find it easier to read in English or your L1? _____________________

4. Can you write in that language? ____

(If yes to 4) Do you find it easier to write in English or your L1? _____________________

5a. Have you ever lived in another country? If yes, which one? _________________________________

5b. If yes, did you go to school in that country? ___________________________

6. What age/school year did you start at school (in England)? __________________________

7. How often do you speak English at home?

a. Never b. Sometimes c. Most of the time d. All of the time

8. How often do you speak your L1 at home?

a. Never b. Sometimes c. Most of the time d. All of the time

9. At home, do you read books in English or your L1?

a. Only English b. Mostly English c. Both equally d. Mostly L1 e. Only L1

10. At home, do you practice maths in English or your L1?

a. Only English b. Mostly English c. Both equally d. Mostly L1 e. Only L1

11. At home, do you watch films and TV in English or your L1?

a. Only English b. Mostly English c. Both equally d. Mostly L1 e. Only L1

12. What language(s) do you **speak,** and with who?

	Only English	**Mostly English**	**Both** English and another language equally	**Mostly not English**	**Only another language**
Parents/Guardians					
Brothers/Sisters					

Other family					
Friends					

Appendix 5: Parent Home Learning Questionnaire

Home-Learning Questionnaire

This questionnaire is part of the research on the relationship between language and maths in EAL children being carried out by Evie Smith from The University of York. Last year you (or another parent/guardian of your child) gave consent for me to carry out some tasks with your Year 3 or Year 5 child in school, and to repeat those tasks again this year, now that they are in Year 4 or Year 6. Given the school closures earlier this year, this survey has been added to the project to give me the opportunity to investigate the impact of these closures and the shift to home-schooling on my data. I would be very grateful if you could complete this short survey - it should take no longer than 10 minutes to complete.

Please note:

- This information will only be used to investigate the project data and will only be accessible to me (Evie Smith).

- Your child's name is asked for just so that I can match your survey data with my existing data - the data will then be anonymised by replacing your child's name with a number code.

If you have any questions, you are welcome to email me at ecs515@york.ac.uk .

---

*Required

1. Child's name: *

____

2. Child's school year: *

Mark only one oval.

◯ Year 4

◯ Year 6

3. Your relationship to child: *

4. Your age *

5. Did your child attend school at all during the lockdown (between the 23rd of March and the end of the summer term)? * *Mark only one oval.*

- Yes
- No

6. If your child did attend school during the lockdown, for how long/how many weeks?

Languages at home

7. Is your child growing up with more than one language? *

Mark only one oval.

- Yes
- No

8. If YES, what language(s) does your child UNDERSTAND in addition to English? If NO to the previous question, please skip the following questions and proceed to the next section.

9. What language(s) does your child SPEAK in addition to English?

10. What language(s) does your child READ in addition to English?

11. What language(s) does your child WRITE in addition to English?

12. What level of SPOKEN English do you and your partner (if applicable) have?

Mark only one oval per row.

	Beginner	Low-intermediate	Intermediate	High-intermediate	Native-like	Native
You	⬭	⬭	⬭	⬭	⬭	⬭
Your partner (if applicable)	⬭	⬭	⬭	⬭	⬭	⬭

13. What level of WRITTEN English do you and your partner (if applicable) have?

Mark only one oval per row.

	Beginner	Low-intermediate	Intermediate	High-intermediate	Native-like	Native
You	⬭	⬭	⬭	⬭	⬭	⬭
Your partner (if applicable)	⬭	⬭	⬭	⬭	⬭	⬭

Home Schooling

14. On average, how many days per week did your child engage in any school work during the lockdown? * *Mark only one oval.*

0 days

1 day

2 days

3 days

4 days

5 days

15. On average, how many days per week did your child engage in MATHS work during the lockdown?

Mark only one oval.

0 days

1 day

2 days

3 days

4 days

5 days

16. On average, how many days per week did your child engage in LITERACY work during the lockdown?

Mark only one oval.

0 days

1 day

2 days

3 days

4 days

5 days

17. During the lockdown, what is the average time your child spent on schoolwork each day they that did some?

Mark only one oval.

0-30 minutes

30 minutes - 1 hour

1-2 hours

2-3 hours

More than 3 hours

18. In general, did your child complete their school work during the lockdown...

Tick all that apply.

By themselves

With the help of a parent

Alongside their sibling(s) (if applicable)

19. How do you think your child found the work set for them over lockdown?

Mark only one oval.

Very easy

Easy

Moderately difficult

Difficult

Very difficult

20. What barriers to your child's home learning experience did you experience during the lockdown (if any)? *

Tick all that apply.

- [ ] Lack of motivation from your child
- [ ] Lack of parent/guardian time
- [ ] Home distractions (e.g., siblings, noise)
- [ ] Lack of internet access
- [ ] Lack of access to the required technology/devices
- [ ] Your level of English proficiency
- [ ] Your confidence in your home-schooling ability

Other: [ ] ______________________

The home environment during lockdown

21. What devices does your child have access to at home? *

Tick all that apply.

- [ ] Laptop
- [ ] Desktop computer
- [ ] Tablet/iPad
- [ ] Smartphone
- [ ] None

Other: [ ] ______________________

22. Roughly how many books do you have in your home? *

Mark only one oval.

- ( ) 0-10
- ( ) 10-30
- ( ) 30-50
- ( ) 50-100
- ( ) 100-150
- ( ) Over 150

23. During the lockdown, roughly how often did your child engage in the following activities at home? *

Mark only one oval per row.

	Every day	Every other day	Once or twice a week	Less often	Never
Reading	⬭	⬭	⬭	⬭	⬭
Watching TV	⬭	⬭	⬭	⬭	⬭
Playing on educational apps or games	⬭	⬭	⬭	⬭	⬭

24. How much did your child engage in the following activities at home during the lockdown COMPARED TO USUAL? *

Mark only one oval per row.

	A lot more than usual	A bit more than usual	The same amount as usual	A bit less than usual	A lot less than usual
Reading	⬭	⬭	⬭	⬭	⬭
Watching TV	⬭	⬭	⬭	⬭	⬭
Playing on educational apps or games	⬭	⬭	⬭	⬭	⬭

25. If you wish, you may add any additional comments about any topic covered in the survey here:

Appendix 6: Child Home Learning Questionnaire

<u>Child Home Learning Questionnaire</u>

1. Did you attend school during the lockdown/Are your parents key workers? YES NO
   If YES, how long for? ____

2. Who did you live with during the lockdown? ____

3. If EAL, during the lockdown, what language did you speak at home?
   a. Only English b. Mostly English c. Both equally d. Mostly L1 e. Only L1

4. Do you have any brothers or sisters? YES NO
   If YES, how many and how old are they? ____

   If YES and EAL, what language do you speak with them? _________________________________

   Who did you play with most during the lockdown? _______________________________________

5.
   a) Did you do any home schooling? YES NO
   b) If YES, who home-schooled you? ____

   c) If YES and SIBLINGS, were you home-schooled together? ___________________________

   d) If YES, how many days per week? 5 4 3 2 1 Less often

   e) If YES, how long for per day? a. <1 hour b. 1-2 hours c. 2-3 hours d. 3-4 hours e. >4 hours

   f) If YES, how many days per week did you do…

	<u>5</u>	**<u>4</u>**	**<u>3</u>**	**<u>2</u>**	**<u>1</u>**	**<u>Less often</u>**
Literacy						
Maths						

   g) If YES and EAL, what language were you home-schooled in? ___________________________

   h) If YES, how much did you enjoy it? a. A lot b. A bit c. Not much d. Not at all

   i) If YES, did you enjoy it more or less than school? a. A lot more b. A bit more c. The same
   d. A bit less e. A lot less

   j) If YES, how much do you think you learnt? a. A lot b. A bit c. Not much d. Nothing

k) If YES, did you learn more or less than in school? a. A lot more b. A bit more c. The same d. A bit less e. A lot less

l) If YES, did your teachers send you the work? YES NO

m) If YES, what technology did you use? ____

6. How many days per week did you talk to your teacher during lockdown?
   5 4 3 2 1 Once every 2 weeks Less often Never

7. How many books does your family have at home? a. Lots b. Quite a lot c. Not many d. None
8. During lockdown, how often did you read…

	>Once a day	**Once a day**	**Once every 2 days**	**Once/twice a week**	**Less often**	**Never**
By yourself?						
With an adult?						
(If EAL) English books?						
(If EAL) L1 books?						

9. During lockdown, did you read more or less than usual?
   a. A lot more b. A bit more c. The same as usual d. A bit less e. A lot less

10. During lockdown, how often did you watch TV…

	>Once a day	**Once a day**	**Once every 2 days**	**Once/twice a week**	**Less often**	**Never**
In English?						
(If EAL) In your L1?						

11. During lockdown, did you watch TV more or less than usual?
    a. A lot more b. A bit more c. The same as usual d. A bit less e. A lot less

12. What did you find fun during lockdown?
    ____

13. What is better now than during lockdown?____

14. How are you finding literacy in school now?

    a. Much easier than before b. A bit easier than before c. The same as before

    d. A bit harder than before e. Much harder than before

15. How are you finding maths in school now?

    a. Much easier than before b. A bit easier than before c. The same as before

    d. A bit harder than before e. Much harder than before

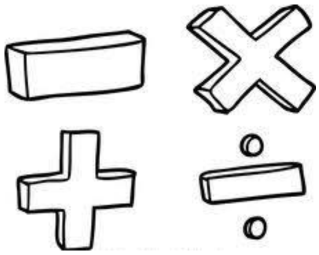
16. How much are you enjoying school now?

    a. A lot b. A bit c. Not much d. Not at all

Appendix 7: Bespoke Year 3-4 and Year 5-6 Arithmetic Computation Tasks

Participant Number: ___________

Date: ___________



$$2 \text{ x } 9 =$$

$$65 - 31 =$$

$$40 \div 10 =$$

$$9 + 3 + 5 =$$

$$70 – 52 =$$

12 ÷ 2 =

8 x 11 =

162 - 45 =

20 ÷ 5 =

31 + 47 =

6 x 5 =

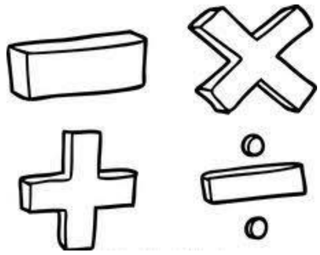
$16 \div 2 =$

$125 - 36 =$

$82 + 27 =$

$22 \div 2 =$

Participant Number: __________
Date: __________



$587 + 155 =$ ☐

$120 \div 8 =$ ☐

$60 - 17 =$ ☐

$8 \times £9.50 = £$ ☐

$376 \div 4 =$ ☐

1½ hrs – 35min = ☐ min

$1.8 + 2.6 =$ ☐

$225 \div 25 =$ □

$1 - \frac{1}{5} - \frac{2}{5} =$ □

80p x 3 = £ □

£17 ÷ 2 = £ □

$80 - 11 - 42 =$ □

$\frac{1}{2} + \frac{1}{8} =$ □

180 x 9 = □

£2.45 - £1.87 = □

Appendix 8: Bespoke Year 3-4 and Year 5-6 WPS Tasks

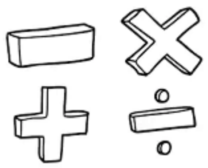
Participant Number: __________
Date: __________

1	There are 6 teams in the school football tournament. Each team has 5 players. How many children are taking part altogether? ☐ = ☐
2	Louise has 70p. She buys a packet of crisps which costs 52p. How much money will she have left? ☐ = ☐
3	There are 16 gloves in the cloakroom. Alisha sorts them into pairs of 2. How many pairs of gloves are there? ☐ = ☐
4	Carlos wants to buy one bread roll and one cake. Bread rolls cost 31p and cakes cost 47p. How much will he need to pay? ☐ = ☐
5	A teacher had 125 crayons in his classroom at the start of the year. 36 crayons have now been lost. How many crayons are left in the classroom? ☐ = ☐

6	Hassan has 20 sweets to share between 5 people. How many sweets does each person get? ☐ = ☐
7	In each packet of pens there are 2 red pens. How many red pens are there altogether in 9 packets? ☐ = ☐
8	Mrs Patel has a packet of 65 stickers. She gives one sticker to each child in her class. There are 31 children in her class. How many stickers does she have left over? ☐ = ☐
9	Nadir has 22p in 2p coins. How many 2p coins does he have? ☐ = ☐
10	Priya has 82 marbles. Her friend Ethan gives her another 27 marbles. How many marbles does Priya have now? ☐ = ☐
11	Daniel reads 8 books every week. How many books will he read in 11 weeks? ☐ = ☐
12	Chloe is tidying away 40 colouring pencils. Each packet holds 10 pencils. How many packets will she need?

	[ ] = [ ]
13	There are 162 children in a school. 45 children are going on a school trip. How many children are not going on the trip? [ ] = [ ]
14	Samantha has 9 conkers. Her sister gives her 3 conkers, and then she finds another 5 conkers on the way to school. How many conkers does she have now? [ ] = [ ]
15	A teacher shares 12 pencils equally between 2 children. How many pencils does each child get? [ ] = [ ]

Participant Number: _________
Date: _________



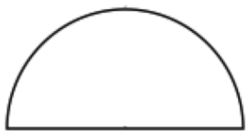
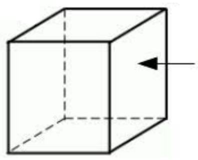
1	A desk is 1.8m wide, and a wardrobe is 2.6m wide. How much wall space would they take up when placed side by side? =
2	376 children are going on a school trip to the theatre. There are 4 coaches to take them there. How many children should go on each coach? =
3	Lucy's mum bakes 80 cupcakes. She gives 11 away to her friends, and sells 42 in a cake sale. How many cupcakes does she have left? =
4	A bag of apples costs 80p. In pounds and pence, how much do 3 bags of apples cost? = £
5	Abdul is tidying up the Lego bricks in his classroom. He collects 225 bricks altogether, and needs to sort them into boxes of 25. How many boxes will he need? =
6	Sajid's dad has baked a cake. Sajid eats $\frac{1}{5}$ of the cake and his dad eats $\frac{2}{5}$ of the cake. What fraction of the cake is left?

	=
7	At a cake sale, ½ of the cakes were sold in the first hour. In the second hour another ⅛ were sold. What fraction of the cakes was sold altogether? =
8	Jamil's dad spent £17 on 2 DVDs which both cost the same amount of money. How much did each DVD cost? = £
9	Hayley has 60 skittles.17 of Hayley's skittles are red. She doesn't like red skittles, so gives the red ones to her brother. How many skittles does she have left? =
10	Ruby can read 180 words per minute. How many words can she read in 9 minutes? =
11	George's teacher has asked him to arrange 120 chairs into 8 equal rows in the school hall. How many chairs should he put in each row? =
12	Caroline is saving up to buy a magazine which costs £2.45. So far, she has saved £1.87. How much more money does she need to save to buy the magazine?

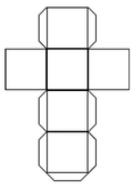
	[ ] = [ ]
13	At a football match this week there were 587 spectators. This was155 fewer spectators than last week. How many spectators were there last week? [ ] = [ ]
14	Casper buys 8 books at the price of £9.50 each. How much does he spend altogether? [ ] = £ [ ]
15	Harry is watching a film which is 1 and a half hours long. So far, he has watched 35 minutes of the film. How many minutes of the film does he have left to watch? [ ] = [ ]

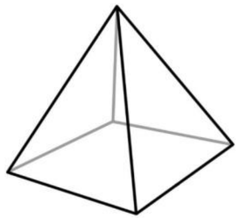
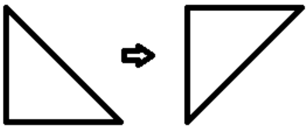
Appendix 9: Bespoke Year 3-4 and Year 5-6 Mathematical Vocabulary Tasks

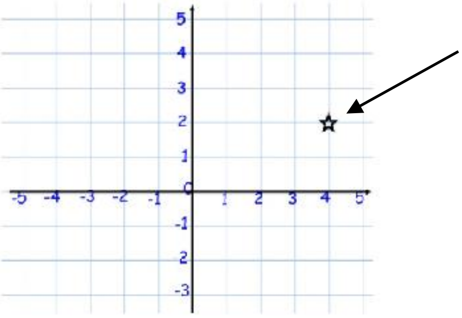
1	What is a <u>triangle</u>? A) A shape with 4 sides. B) A shape with 3 sides. C) Half of a circle. D) A shape with 5 sides.
2	The <u>sum</u> of two numbers is… A) The two numbers added together. B) The smaller number taken away from the bigger number. C) The two numbers multiplied together. D) The bigger number.
3	How many sides does a hexagon have? A) 3 C) 7 B) 6 D) 5
4	What does <u>estimate</u> mean? A) Count how many there are. B) Guess how many there are. C) Take some away. D) Add some more.
5	This is a picture of a ten pence _______. A) Pound C) Note 

	B) Coin D) Penny
6	When you are buying something, what is change? A) How much money the item costs. B) The money you give to the shopkeeper. C) The leftover money you get back from the shopkeeper. D) When items cost less than usual.
7	What is this shape called? A) A semicircle. C) A hemisphere. B) A prism. D) A circle. 
8	What do you use to weigh something? A) A ruler. C) Scales. B) Measures. D) A pen.
9	What part of the cube is the arrow pointing at? A) An edge. C) A head. B) A corner. D) A face. 
10	How do you find the difference between two numbers? A) Add them together. B) Divide the bigger number by the smaller number. C) Take the smaller number away from the bigger number.

	D) Multiply them together.
11	There are 60 ______ in a minute. A) Hours C) Seconds B) Days D) Weeks
12	These two lines are… A) Perpendicular. C) Intersecting. B) Parallel. D) Vertical. 
13	What does height mean? A) How heavy something is. C) How tall something is. B) How much something costs. D) How deep something is.
14	How do you double a number? A) Multiply it by 2. C) Add 2 to it. B) Divide it by 2. D) Subtract 2 from it.
15	When the time is 2:15, you can also say that it is… A) Half past 2. C) Quarter past 2. B) 2 o’clock. D) Quarter to 2.

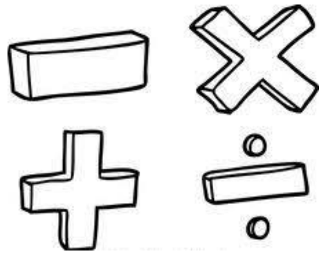
1	What is this a picture of? A) A protractor. B) A set square. C) A compass. D) A ruler. 
2	An <u>acute angle</u> is always… A) Exactly 45 degrees. C) Less than 45 degrees. B) Less than 90 degrees. D) More than 90 degrees.
3	6 is a… A) Negative whole number. C) Positive whole number. B) Positive decimal. D) Negative decimal.
4	What is this? A) A net. C) A graph. B) A rod. D) A map. 
5	What is an angle of 90 degrees called? A) An obtuse angle. C) A reflex angle. B) A right angle. D) A square angle.
6	What is a <u>quadrilateral</u>? A) A circle. C) A triangle. B) Any shape with 5 sides. D) Any shape with 4 sides.
7	Metres, centimetres, grams and kilograms are all _______ of measurement.

	A) Digits C) Proportions B) Units D) Squares
8	What is this? A) A triangular-based pyramid. B) A cone. C) A square-based pyramid. D) A regular pyramid. 
9	<u>Mass</u> is a measure of how ______ something is. A) Heavy C) Deep B) Tall D) Wide
10	In this picture, the triangle has been… A) Translated. C) Reflected. B) Rotated. D) Rounded. 
11	If I walked around all 4 edges of a playground, the total distance I walked would be the _______ of the playground. A) Area C) Angle B) Diameter D) Perimeter
12	Which type of triangle has 3 sides of the same length and 3 angles of the same size? A) Isosceles. C) Scalene. B) Equilateral. D) Right-angled.
13	The ________ of the star are (4,2).

	A) Origins B) Translations C) Coordinates D) Positions 
14	How do you <u>square</u> a number? A) Multiply it by 2. B) Divide it by itself. C) Multiply it by itself. D) Divide it by 2.
15	A number that can only be divided by 1 and itself is called a… A) Whole number. B) Prime number. C) Prime factor. D) Cube number.

Appendix 10: Preliminary bespoke Year 3-4 Arithmetic Computation and WPS Tasks

Participant Number: __________
Date: __________



80 – 43 =

7 + 4 + 5 =

16 ÷ 2 =

3 x 5 =

23 + 6 =

$65 - 31 =$

$7 \times 5 =$

$30 \div 6 =$

$70 - 52 =$

$31 + 47 =$

$40 \div 10 =$

3 x 10 =

9 + 3 + 5 =

28 – 21 =

6 x 7 =

22 ÷ 2 =

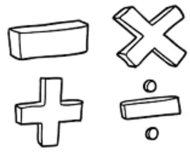
125 – 46 =

$82 + 27 =$

$12 \div 2 =$

$7 \times 2 =$

Participant Number: _________
Date: _________



1	Alisha counts that there are 23 flowers in her garden. After one week, 6 more flowers have grown. How many flowers are there now in Alisha's garden?
2	Clara has 28 toy animals. Her brother Lucas has 21. How many more toy animals does Clara have than Lucas?
3	In each packet of pens there are 4 blue pens and 2 red pens. How many red pens are there altogether in 7 packets?
4	Chloe is tidying away the colouring pencils. Each packet holds 10 pencils. She finds 40 pencils to tidy away. How many packets will she need?
5	A packet of crisps costs 52p. Louise pays for one packet with 70p. How much change will she get?
6	Samantha has 9 conkers. Her sister gives her 3 conkers, and then she finds another 5 conkers on the way to school. How many conkers does she have now?

7	Hassan has 30 sweets to share between 6 people. How many sweets does each person get?
8	A ticket to the cinema costs £3. Freddie goes to the cinema with his friends. They need 5 tickets in total. How much does it cost them altogether?
9	Priya has 82 marbles. Her friend Ethan gives her another 27 marbles. How many marbles does Priya have now?
10	Joe’s sticker book has space for 80 stickers. So far he has collected 43 stickers. How many more stickers does Joe need to complete his sticker book?
11	Pamela, Angus and Romesh have 10 crayons each. How many crayons do they have altogether?
12	A teacher shares 12 pencils equally between 2 children. How many pencils does each child get?

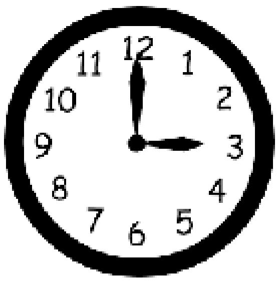
13	Mrs Patel has 31 children in her class. She gets a packet of 65 stickers and gives one to each child in her class. How many stickers does she have left?
14	Sophie has 7 pens, Rina has 4 pens and Charlie has 5 pens. How many pens do they have altogether?
15	Nadir has 22p in 2p coins. How many 2p coins does he have?
16	There are 6 teams in the school football tournament. Each team has 7 players. How many children are taking part altogether?
17	Carlos wants to buy one bread roll and one cake. Bread rolls cost 31p and cakes cost 47p. How much will he need to pay?
18	A teacher had 125 crayons in his classroom at the start of the year. After 2 months, 46 crayons have been lost. How many crayons are left in the classroom?

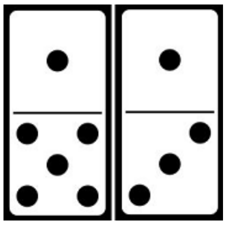
19	Daniel reads 7 books every week. How many books will he read in 5 weeks?
20	There are 16 gloves in the cloakroom. How many pairs of gloves are there?

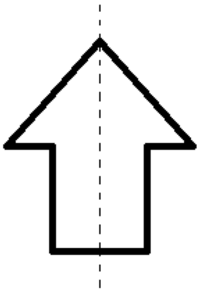
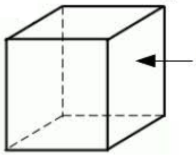
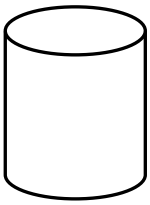
Appendix 11: Preliminary bespoke Year 3-4 Mathematical Vocabulary Task

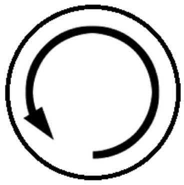
Participant Number: __________
Date: __________

Complete the sentences or answer the questions.
Circle the correct answers.

1	The <u>sum</u> of two numbers is… A) The two numbers added together. B) The smaller number taken away from the bigger number. C) The two numbers multiplied together. D) The bigger number.
2	What is a <u>triangle</u>? A) A shape with 4 sides. B) A shape with 3 sides. C) Half of a circle. D) A shape with 5 sides.
3	What is this a picture of? A) An analogue clock. B) An automatic clock. C) A digital clock. D) A digit clock. 
4	How do you find the <u>difference</u> between two numbers? A) Add them together. B) Divide the bigger number by the smaller number. C) Take the smaller number away from the bigger number. D) Multiply them together.

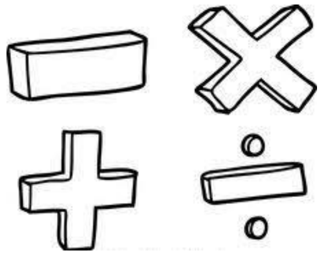
5	How many sides does a hexagon have? A) 3 C) 7 B) 6 D) 5
6	This is a picture of a ten pence _______. A) Pound C) Note B) Coin D) Penny 
7	When you are buying something, what does <u>change</u> mean? A) How much money the item costs. B) The money you give to the shopkeeper. C) The leftover money you get back from the shopkeeper. D) When items cost less than usual.
8	What are these? A) Pegs. C) Cubes. B) Dice. D) Dominoes. 
9	2, 4, 6 and 8 are all ______ numbers. A) Odd C) Strange B) Smooth D) Even
10	What are the parts of an analogue clock which move to show the time called? A) Feet. C) Hands. B) Arms. D) Legs.

11	This picture shows the __________ of the arrow. A) Line of width B) Line of symmetry C) Centre line D) Mirror 
12	What do you use to <u>weigh</u> something? A) A ruler. C) Scales. B) Measures. D) A pen.
13	What part of the cube is the arrow pointing at? A) An edge. C) A head. B) A corner. D) A face. 
14	What does <u>estimate</u> mean? A) Count how many there are. B) Guess how many there are. C) Take some away. D) Add some more.
15	What is this? A) A cube. C) A cuboid. B) A cylinder. D) A cone. 
16	Triangles, rectangles and circles are all… A) Numbers. C) Shapes. B) Units. D) Digits.
17	There are 60 ______ in a minute. A) Hours C) Seconds

	B) Days D) Weeks
18	If someone ran around a room in this direction, they would be running…  A) Backwards. C) Clockwise. B) In reverse. D) Anticlockwise.
19	What does <u>height</u> mean? A) How heavy something is. C) How tall something is. B) How much something costs. D) How deep something is.
20	How do you <u>double</u> a number? A) Multiply it by 2. C) Add 2 to it. B) Divide it by 2. D) Subtract 2 from it.
21	What is the <u>capacity</u> of something? A) How much it costs. C) How wide it is. B) How much fits into it. D) How long it is.
22	When the time is 2:15, you can also say that it is… A) Half past 2. C) Quarter past 2. B) 2 o'clock. D) Quarter to 2.

Appendix 12: Preliminary bespoke Year 5-6 Arithmetic Computation and WPS Tasks

Participant Number: __________
Date: __________



245 – 187 = ☐

587 + 155 = ☐

225 ÷ 25 = ☐

8 x £9 = £ ☐

1.6 + 2.2 = ☐

1½ hrs – 35min = ☐ min

32 x 6 = ☐

96 ÷ 12 = ☐

60 – 17 = ☐

£2.87 + £2.46 = £ ☐

£17 ÷ 2 = £ ☐

6 x 8 = ☐

1179 + 1053 = ☐

80 – 11 – 42 = ☐

80p x 3 = £ ☐

$120 \div 8 = \square$

28min + 37min = $\square$ hr $\square$ min

$1 - \frac{1}{5} - \frac{2}{5} = \square$

$11 \times 12 = \square$

$376 \div 4 = \square$

Participant Number: _________
Date: _________

1	At a football match this week there were 587 spectators. This week there were 155 fewer spectators than last week. How many spectators were there last week?
2	Hayley has 60 skittles.17 of Hayley's skittles are red. She doesn't like red skittles, so gives the red ones to her brother. How many skittles does she have left?
3	Samira's mum runs 11 kilometres every day. How many kilometres will she have run in 12 days?
4	Sarah's mum has 96 smarties. She is making 12 party bags for Sarah's party. How many smarties should she put in each party bag so that each child gets the same amount?
5	Lucy's mum bakes 80 cupcakes. She gives 11 away to her friends, and sells 42 in a cake sale. How many cupcakes does she have left?

6	A desk is 1.6m wide, and a wardrobe is 2.2m wide. How much wall space would they take up when placed side by side?
7	Abdul is tidying up the Lego bricks in his classroom. He collects 225 bricks altogether, and needs to sort them into boxes of 25. How many boxes will he need?
8	Each page of a workbook has 6 questions on it. How many questions are there on 8 pages altogether?
9	Jerome has £2.87 and his brother has £2.46. How much money do they have altogether between them?
10	Harry is watching a film which is 1 and a half hours long. So far, he has watched 35 minutes of the film. How many minutes of the film does he have left to watch?
11	A bag of apples costs 80p. In pounds and pence, how much do 3 bags of apples cost?

12	Jamil's dad bought 2 DVDs which both cost the same amount of money. He spent £17 in total. How much did each book cost?
13	Sajid eats $\frac{1}{5}$ of a cake, and his dad eats $\frac{2}{5}$. What fraction of the cake is left?
14	In one school there are 1179 pupils, and in another school there are 1023 pupils. How many pupils do the two schools have altogether?
15	376 children are going on a school trip to the theatre. There are 4 coaches to take them there. How many children should go on each coach?
16	Casper buys 8 books at the price of £9 each. How much does he spend altogether?
17	Terence worked on his homework for 28 minutes after he got home from school, and then for another 37 minutes after dinner. In hours and minutes, how much time did he spend working on his homework altogether?

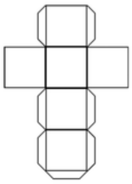
18	Caroline’s sticker book has space for 245 stickers. So far, she has collected 187 stickers. How many more stickers does she need to collect to fill her sticker book?
19	There are 32 children in each class in a school. There are 6 classes in the school. How many children are there in the school altogether?
20	George’s teacher has asked him to arrange 120 chairs into 8 equal rows in the school hall. How many chairs should he put in each row?

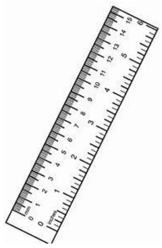
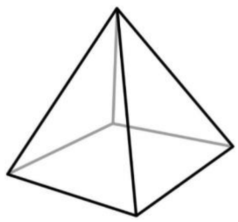
Appendix 13: Preliminary bespoke Year 5-6 Mathematical Vocabulary Task

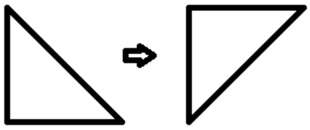
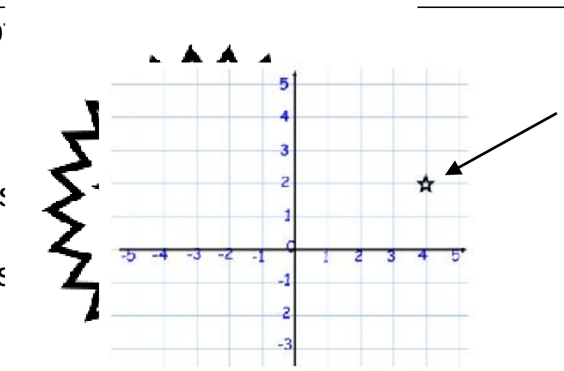
Participant Number: __________
Date: __________

Complete the sentences or answer the questions.
Circle the correct answers.

1	Increasing an amount means to… A) Halve it. C) Make it smaller. B) Make it bigger. D) Divide it by 3.
2	What is the radius of a circle? A) The distance from one side of a circle to the opposite side. B) The distance around the edge of a circle. C) The distance from the middle of a circle to the edge. D) The size of a circle.
3	What is this a picture of? A) A protractor. B) A set square. C) A compass. D) A ruler. 
4	An acute angle is always… A) Exactly 90 degrees. C) Exactly 45 degrees. B) Less than 90 degrees. D) More than 90 degrees.

5	6 is a… A) Negative integer. C) Positive integer. B) Positive decimal. D) Negative decimal.
6	What is this? A) A net. C) A graph. B) A rod. D) A map. 
7	What is a <u>regular polygon</u>? A) A shape with sides of equal length and angles of equal size. B) A shape with sides of equal length and angles of different sizes. C) A shape with sides of different lengths and angles of equal size. D) A shape with sides of different lengths and angles of different sizes.
8	A <u>right angle</u> is an angle of… A) 45 degrees. C) 60 degrees. B) 30 degrees. D) 90 degrees.
9	Which of these units of measurement is smaller than a centimetre? A) A metre. C) A kilometre. B) A mile. D) A millimetre.
10	What is a <u>quadrilateral</u>? A) A circle. C) A triangle. B) Any shape with 5 sides. D) Any shape with 4 sides.

11	What is this? A) A protractor. C) A ruler. B) A number line. D) A quadrant. 
12	What is the arrow pointing to? A) The decimal point. B) The decimal place. C) The decimal unit. D) The decimal fraction. 
13	Metres, centimetres, grams and kilograms are all ______ of measurement. A) Digits C) Proportions B) Units D) Squares
14	What is a <u>quotient</u>? A) The result of multiplying two numbers together. B) The result of adding two numbers together. C) The result of subtracting one number from another number. D) The result of dividing one number by another number.
15	What is this? A) A triangular-based pyramid. B) A cone. C) A square-based pyramid. D) A regular pyramid. 
16	<u>Mass</u> is a measure of how ______ something is. A) Heavy C) Deep B) Tall D) Wide

17	In this picture, the triangle has been… A) Translated. C) Coordinated. B) Rotated. D) Rounded. 
18	If I walked around all 4 edges of a playground, the total distance I walked would be the _______ of the playground. A) Area C) Angle B) Diameter D) Perimeter
19	Which type of triangle has 3 sides of the same length and 3 angles of the same size? A) Isosceles. C) Scalene. B) Equilateral. D) Right-angled.
20	The ________ o  A) Origins B) Translation C) Coordinate D) Positions

Appendix 14: Descriptive Statistics for the T1 Linguistic and Cognitive Variables before Multiple Imputation

Mean (SD) raw scores split by language group; whole sample, Year 3 and Year 5

Measure	Whole sample		Year 3		Year 5	
	EAL	FLE	EAL	FLE	EAL	FLE
Reading Accuracy	50.86	52.75	47.33	44.89	54.92	58.19
	(10.02)	(10.04)	(7.24)	(7.90)	(11.47)	(7.47)
Reading Rate	64.68	66.23	57.33	54.44	73.15	74.38
	(15.07)	(16.95)	(13.12)	(18.48)	(12.85)	(9.63)
Reading Comprehension	53.75	59.07	50.07	52.83	58.00	63.38
	(9.36)	(10.27)	(6.12)	(8.83)	(10.80)	(9.01)
Word Reading	65.93	65.91	62.40	54.39	70.00	73.88
	(15.07)	(16.21)	(11.88)	(15.58)	(17.70)	(11.19)
Expressive Vocabulary	23.25	27.57	19.60	24.33	27.46	29.81
	(6.79)	(4.81)	(6.17)	(3.99)	(4.82)	(4.02)
Receptive Vocabulary*	100.68	115.45	85.58	105.79	114.62	123.41
	(21.51)	(17.58)	(11.86)	(14.34)	(18.92)	(16.22)
Mathematical Vocabulary*	15.11	18.72	8.47	9.65	22.77	24.65
	(7.94)	(7.91)	(3.50)	(1.84)	(2.95)	(3.21)
Phonological Awareness*	21.08	22.03	21.00	21.64	21.15	22.35
	(5.24)	(5.44)	(4.41)	(5.15)	(6.08)	(5.81)
Phonological Memory*	17.00	15.45	16.00	14.93	17.92	15.88
	(3.10)	(2.39)	(2.70)	(2.02)	(3.25)	(2.64)
RAN (time in seconds)*	38.68	42.45	42.92	46.07	34.77	39.47
	(7.49)	(9.60)	(7.34)	(11.51)	(5.33)	(6.65)
Verbal Working Memory*	12.24	10.84	11.67	9.43	12.77	12.00
	(4.25)	(4.23)	(3.52)	(4.18)	(4.90)	(4.02)
Non-verbal Ability	11.93	13.64	10.13	11.28	14.00	15.27
	(4.21)	(4.44)	(3.48)	(4.13)	(4.12)	(3.94)

Note. * indicates variable had missing data

Appendix 15: Correlations between the Linguistic and Cognitive Variables before Multiple Imputation

Partial correlations between all linguistic and cognitive variables, controlling for year group

	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.
1. Reading Accuracy											
2. Reading Rate	.80***										
3. Reading Comprehension	.57***	.60***									
4. Word Reading	.87***	.86***	.61***								
5. Expressive Vocabulary	.41***	.45***	.62***	.39***							
6. Receptive Vocabulary†	.35**	.41**	.63***	.30*	.78***						
7. Mathematical Vocabulary†	.44***	.46***	.58***	.46***	.63***	.65***					
8. Phonological Awareness†	.07	-.06	.01	.01	.24	.15	.19				
9. Phonological Memory†	.35**	.43**	.10	.42**	.10	.15	.18	.20			
10. RAN (time in seconds)†	-.32**	-.54***	-.23	-.50***	-.02	-.10	-.21	-.13	-.48***		
11. Verbal Working Memory†	.37**	.33*	.13	.37**	-.02	.09	.11	.12	.53***	-.42**	
12. Non-verbal Ability	.28*	.13	.35**	.28*	.36**	.36**	.33**	.33*	-.04	.04	.05

Note. * indicates $p < .05$, ** indicates $p < .01$, *** indicates $p < .001$; † indicates variable had missing data

Appendix 16: Descriptive Statistics for the T1 Mathematical Variables before Multiple Imputation

Mean (SD) raw mathematical scores split by language group; whole sample, Year 3 and Year 5

Measure	Whole sample		Year 3		Year 5	
	EAL	FLE	EAL	FLE	EAL	FLE
Arithmetic Computation	15.36	16.25	10.33	7.39	21.15	22.38
	(6.34)	(8.44)	(2.26)	(3.76)	(4.06)	(4.16)
Mathematical WPS*	14.48	15.48	7.75	7.36	20.69	22.18
	(7.35)	(8.72)	(3.25)	(5.21)	(3.38)	(3.91)
Difference in Scores on	1.28	-0.10	2.17	-0.50	0.46	0.24
Bespoke Tasks*	(2.85)	(2.36)	(3.10)	(2.03)	(2.44)	(2.61)
Arithmetic Fluency*	77.92	67.74	63.92	43.79	90.85	87.47
	(26.25)	(37.84)	(18.88)	(19.19)	(25.97)	(38.35)

Note. * indicates variable had missing data

Appendix 17: Correlations between the Mathematical Variables before Multiple Imputation

Partial correlations between the mathematics measures, controlling for year group

	1.	2.	3.	4.
1. Arithmetic Computation				
2. Mathematical WPS†	.78***			
3. Difference in Scores on Bespoke Tasks†	.33*	-.34*		
4. Arithmetic Fluency†	.77***	.66***	.16	

Note. * indicates $p < .05$, ** indicates $p < .01$, *** indicates $p < .001$; † indicates variable had missing data

List of Abbreviations

BPVS3	British Picture Vocabulary Scale: 3rd Edition
CTOPP-2	Comprehensive Test of Phonological Processing Second Edition
DfE	Department for Education
DIF	Differential Item Functioning
DTWRP	Diagnostic Test of Word Reading Processes
EAL	English as an Additional Language
FLE	First Language English
FSM	Free School Meals
GLD	Good Level of Development
KMO	Kaiser-Meyer-Olkin Measure of Sampling Adequacy
KS1	Key Stage 1
KS2	Key Stage 2
KS4	Key Stage 4
L1	First Language
L2	Second Language
MCAR	Missing Completely at Random
MD	Mathematical Disabilities
PCA	Principal Components Analysis
PiE	Proficiency in English
RAN	Rapid Automatised Naming
SES	Socioeconomic Status
SVR	Simple View of Reading
T1	Time 1
T2	Time 2
TOBANS	Test of Basic Arithmetic and Numeracy Skills
WASI-II	Wechsler Abbreviated Scale of Intelligence – Second Edition
WMTB-C	Working Memory Test Battery for Children
WPS	Word Problem Solving
YARC	York Assessment of Reading Comprehension

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