Naturalistic Observations of Individual Differences in Children's Home Environments

Katrina Helen d'Apice

PhD

University of York

Education

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Abstract

This thesis investigated associations between early life home environments and children's linguistic, cognitive and behavioural outcomes. Markers of the home environment included characteristics of adult speech that children were exposed to (i.e., the quantity, lexical diversity and vocabulary sophistication), parenting behaviours, and literacy behaviours and beliefs. For children's outcomes, their language (i.e., lexical diversity and vocabulary sophistication), non-verbal cognitive abilities, and behavioural responses were assessed.

Naturalistic home observations were collected from 107 children, aged 24 to 48 months, and their families using LENA digital audio-recorders. All families completed 3 day-long audio-recordings for an average of 15.06 hours per day (*SD* = 1.87), making this the largest naturalistic observational study of British home environments to date.

This thesis makes an original contribution by 1) exploring the association between early life experiences of language and parenting on children's language, cognitive, and behavioural differences using naturalistic observations, 2) being the first to assess the lexical diversity and vocabulary sophistication of naturalistic speech collected by LENA audio-recorders, 3) conducting a novel psychometric assessment of parenting and child behaviours derived from audio-recordings, 4) providing empirical evidence of extreme within-family variability in children's language exposure, which was not previously recognised, and 5) showing that parental literacy behaviours influence children's cognitive abilities independent of the adult speech that they hear in the family home.

The studies contained within this thesis provide support for the environmental specificity hypothesis which states that different aspects of child development have unique environmental predictors. The findings confirm the importance of language input for children's language development and align with the usage-based theory of language acquisition. Overall, the environmental factors studied here were found to be important for children's development and extremely dynamic. Utilising digital technologies to harness these dynamic environments may bring us closer to understanding how best to improve children's outcomes.

List of Contents

List of Tables

List of Figures

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Author's Declaration

The following papers that are contained within this thesis have been published or submitted for publication.

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This work has been collaborative with my PhD supervisor, Sophie von Stumm, and also Rachel M Latham.

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

Written Statement of Co-Authored Work

Katrina d'Apice completed the data collection, preparation, analyses and writing up of all papers included in this thesis. Sophie von Stumm designed the studies, obtained the funding and supervised all aspects of the work. Rachel M Latham assisted with the behavioural analysis detailed in paper 1. All authors edited and approved the manuscripts.

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I hereby confirm that the above statement is correct.

Katrina d'Apice Signature: _K H d'Apice__ Date:_27/07/2019__

Sophie von Stumm Signature: ___ _ Date:_29/07/2019___

Rachel M Latham Signature: _Rachel Latham__ Date: _29/07/2019__

1 Integrative Chapter

In this integrative chapter, I will review different theoretical perspectives of child development to frame my work. First, I will outline 3 social environmental theories which propose that adult-child interactions within the environment are vital for child development and hence underpin the findings within this thesis. These social environmental theories include 1) ecological systems theory (Bronfenbrenner, 1979), 2) social learning theory (Bandura, 1971), and 3) the usage based theory of language acquisition (Tomasello, 2003). Next I'll discuss alternative theoretical perspectives which emphasise the biological basis for child development, such as the universal grammar theory (Chomsky, 1972), and behavioural genetics (Knopik, Neiderhiser, DeFries, & Plomin, 2017). Lastly, I will review the environmental and age specificity hypotheses (Wachs & Gruen, 1982) because they are the framework upon which this thesis is based.

After reviewing the theoretical background, I will discuss the importance of naturalistic home observations for assessing early life home environments. Then I will describe the sample upon which the studies are based before introducing LENA technology. Following this, I will summarise the 3 papers and explain how they form a coherent body of work. In addition, I will describe the original contribution that this thesis makes to the field of developmental science. Finally, I will discuss the role of socioeconomic status (SES) in studies of the home language environment.

The interactions that occur within the family home exert considerable influence on young children's development (Hart & Risley, 1995; Hoff, 2003; Rowe, 2012). However, previous studies of the home environment often failed to document typical adult-child interactions because they employed obtrusive or structured observations, which can create artificial conditions. To overcome this limitation, the studies within this thesis used unobtrusive naturalistic observations to assess early life home environments, which were free from observer biases and thus maintained high ecological validity.

Previous studies of the home environment tended to focus on one attribute, such as language, but ignored other factors that may exert an influence on child outcomes. For example, Ramírez-Esparza, García-Sierra and Kuhl (2014) assessed if language style (i.e., parentese or adult speech) and context (i.e., one to one or group interactions) in the family home were associated with children's language outcomes. However, they failed to account for potential confounds that might influence children's language such as their exposure to literacy behaviours. To address this issue, this thesis will investigate multiple factors of the home environment, including language, parenting, and parental literacy behaviours. The aim of this thesis was to explore which characteristics of the home environment are most important for children's cognitive, language, and social-emotional development, and whether children's age moderated these influences. To achieve this aim, I used digital audio-recorders to unobtrusively observe naturalistic interactions between 107 children, aged 24 to 48 months (M = 32, SD = 6.5), and their families over 3 days (M = 15.06 hours per day, SD = 1.87). In addition, parents administered a cognitive testing booklet to their child and reported on their own literacy behaviours and their child's non-verbal cognitive ability. With these data, I confirmed and extended previous findings on the specific associations between language input, literacy and parenting behaviours, and children's language, cognitive ability and their behavioural responses.

This thesis comprises 3 papers, each of which addresses a distinct research question: Paper 1: How are the quantity and lexical diversity of adult speech, and parenting behaviours associated with children's language, cognitive and behavioural outcomes? Paper 2: How do adult speech and literacy behaviours compare in their association with children's language and cognitive outcomes? Paper 3: Does children's age moderate the associations between the quantity, lexical diversity or vocabulary sophistication of adult speech and children's language and cognitive outcomes?

1.1 Theoretical Background

The course of a child's linguistic, cognitive and behavioural development is thought to be steered by their genetics, the environment to which they are exposed and the interplay between these two factors, which all play a part in creating unique individuals. If we first consider the social environment which children encounter, it is multi-faceted, comprising numerous interactions which the child may be directly or indirectly influenced by. Broad theories of child development such as ecological systems (Bronfenbrenner, 1979, 2005) and social learning theories (Bandura, 1971) highlight the importance of adult-child interactions to aid development. Rooted within social interactions, the usage based theory of language acquisition posits that language input is imperative for children's linguistic development (Tomasello, 2003). Taken together, these social environmental theories suggest that adult-child interactions affect child development.

An alternative perspective is that children's developmental differences can be largely attributed to their inherited DNA differences (Plomin, 2018). Indeed, an overwhelmingly large body of research suggests that genetic factors account for at least 50% of the differences in characteristics that we can observe between people (Polderman et al., 2015). However, genetic influences on phenotypic differences are weak in early life, with the shared family environment playing a significant role in children's outcomes (Haworth et al., 2010).

Currently, the existing empirical evidence base does not allow inferring if environmental and genetic influences on children's developmental differences are domain specific or exert their influence across multiple domains. For example, language input may only influence children's language outcomes, or it may also contribute to non-verbal cognitive ability and behavioural responses (Hart & Risley, 1995). Likewise, genetic effects maybe specific to one trait or generalist (Plomin & Kovas, 2005).

The focus of this thesis is on associations between the social environment and child outcomes, although these are likely to be confounded by genetic effects. However, it is important to explore environmental impacts on child development because they have the potential to be altered through targeted interventions and in turn improve child outcomes (Dowdall et al., 2020; O'Connor, Matias, Futh, Tantam, & Scott, 2013; Suskind et al., 2015). In the following, I will briefly review the three leading 'social environmental theories' of child development, before detailing the behavioural genetic perspective, after which I will discuss the environmental and age specificity hypotheses. I note that environmental and genetic perspectives are not mutually exclusive but complement each other and can be integrated: Individual differences in development are due to environmental and genetic influences, which correlate and interact (Plomin, 2018; Polderman et al., 2015).

1.1.1 Ecological Systems Theory

Bronfenbrenner's ecological systems theory suggests that adults within children's proximal environment have most influence on their cognitive and behavioural development (Bronfenbrenner, 1979). Ecological systems theory parses the environment into 5 systems: first, the microsystem comprises interactions that are most proximal to the child, which in early life is interactions with family members. Second, the mesosystem refers to interactions between individuals within the microsystem, for example a child with an impoverished home environment may be less well equipped to deal with issues at school. More distally, the third system, the exosystem, involves interactions that indirectly impact the child, for example a mother's experience at work may affect the relationship she has with her child at home. The fourth, broader system, termed the macrosystem, refers to the culture and society in which a child lives. For example, SES is a macrosystemic factor that affects child development. The interactions that occur within these 4 systems are further influenced by the chronosystem, which represents that experiences change over time, both within the child's life and in sociohistorical contexts. For example, women's liberation was a sociohistorical change that may result in a mother working outside of the family home and thus, spending less time with her child.

The systems that Bronfenbrenner describes are all important for child development. However, for this thesis I will focus on interactions within the microsystem and specifically the family home, because these interactions are thought to have the greatest effect on child outcomes (Bronfenbrenner, 1979). In addition, I will consider SES, a macrosystemic factor, in my analyses because an abundance of studies suggest SES has considerable influence on child outcomes (Hoff, 2003; McGillion et al., 2017; Pace, Luo, Hirsh-Pasek, & Golinkoff, 2017; Rowe, 2008), although it is not the focus of my studies.

1.1.2 Social Learning Theory

Social learning theory posits that children learn from their experience of social interactions (Bandura, 1971). In young children, the main source of these experiences is the parent-child relationship and the family context (O'Connor et al., 2013). The hallmark of social learning theory is observational learning, which refers to children first observing a behaviour, then identifying the consequences of the behaviour, and finally imitating the behaviour if they desire to do so. Because this sequence includes a cognitive processing stage (i.e., when the child is weighing up the consequences of a behaviour), observational learning places the individual as the agent of their own learning.

Bandura (1992) suggests 4 subprocesses that are necessary for social learning: 1) attention, the individual attends to the behaviour of another, 2) retention of information, 3) production of the behaviour, and 4) motivation. The last stage is dependent on whether an individual chooses to incorporate the modelled behaviour into their own responses, this decision is based on their perceived consequences of the behaviour which is reinforced vicariously from situations they have witnessed.

Vicarious reinforcement refers to observing another person being either positively or negatively reinforced by their behaviour, and therefore this knowledge becomes engrained into one's own internal model. This process of social learning is thought to be more efficient that operant conditioning because the individual can learn through other people's actions without having to trial different behaviours to ascertain which is most advantageous (Bandura, 1971). For example, if a child observes their parent saying ‘thank you’ to another adult, and the adult responds with a smile and warmth, then the child learns that these words are likely to be met with a positive response and so they are advantageous and worth incorporating into their own responses. Likewise, young children who observe frequent aggressive behaviours in the family home display more aggression themselves compared to children who rarely witness such behaviours (Onyskiw & Hayduk, 2001). Therefore, the child learns that it is acceptable to be aggressive because in the modelling, aggressive behaviour appears to be an appropriate reaction to a situation.

In addition to child behaviour, social learning theory can be applied to language acquisition and non-verbal cognitive development. For example, with language learning, a child must first hear and attend to a word, retain its sound and meaning, produce the word, and be motivated by reinforcement to continue producing the word. For non-verbal cognitive development, a child may observe another child (e.g., in a playground or at the beach) building a sandcastle. If the observed child is rewarded by their parent for their creation, the first child may decide to imitate this behaviour with the expectation of positive reinforcement from their own parent.

The family is a social unit in which critical social learning occurs (Kunkel, Hummert, & Dennis, 2006). Family systems theory (Minuchin, 1988) posits that families are more than just the sum of its parts, they are an integrated whole and therefore the wider family context matters for children's socioemotional adjustment (Schoppe, Mangelsdorf, & Frosch, 2001). For example, co-parenting (the relationship between mothers and fathers) and the triadic relationship between mothers, fathers and the child (Schoppe et al., 2001). Furthermore, preferential treatment of siblings also contributes to a child's behavioural adjustment (Oliver & Pike, 2018).

Previous developmental research mainly focussed on the influence of maternal caregiving to children's development, however fathers also play an invaluable role in influencing child outcomes (Baker, 2013; Quach et al., 2018). Given that a child interacts with all family members in the home environment, analysis undertaken in this thesis will consider all adult talk that a child is exposed to, and the influence of both mothers and fathers parenting.

1.1.3 Language Theories

Language acquisition is the process by which children acquire the words, syntax, and semantics to effectively convey their thoughts and to understand others. Although most children acquire language with relative ease, there are striking individual differences in the rate of language acquisition (Bornstein, Hahn, Putnick, & Suwalsky, 2014; Hart & Risley, 1995). This is of particular importance as language acquisition predicts later socio-emotional functioning, cognitive abilities and academic achievement (Goldin-Meadow et al., 2014; Morgan, Farkas, Hillemeier, Hammer, & Maczuga, 2015; Petersen et al., 2013).

All language acquisition researchers agree that exposure to speech is essential for acquiring a language (Huttenlocher et al., 2010), although theories disagree in the amount of influence that language input has. Theories of language acquisition usually fall into one of two areas, empiricism and nativism. Empiricist theories, such as usage-based theory, posit that behaviour results from learning and therefore language skills develop from observing and listening to an external model of language. By comparison, nativist theories, such as universal grammar theory, suggest that children possess an innate device to understand the structure of language, and therefore environmental influences are trivial (Chomsky, 1959).

My PhD research is most aligned with empiricist theories, such as usage-based theory, which emphasise the importance of language input for children's language acquisition (Tomasello, 2003; Jones & Rowland, 2017). However, my research is focused on understanding the factors that underlie individual differences in children's language acquisition and therefore, the overview of language theories below provides a general background on language learning.

Rooted in social interactions, the main principles of usage-based theory state that children first acquire language by understanding how others use language and then the grammatical structure emerges from their own language use (Langacker, 1987; Tomasello, 2003). Usage-based theory assumes that children use general cognitive skills for language acquisition such as intention-reading and pattern-finding. Intention-reading is used for inferring another speaker's intentions and is responsible for symbol acquisition and the functional components of language (Nelson, 1981), while pattern-finding is required to create abstract linguistic constructions – hence researchers in this field are often referred to as constructivists (Tomasello, 2003).

In opposition to usage-based theories, Chomsky (1959) argued that since language is a complex skill to acquire, it had to be explained in biological rather than social terms. He argued that language input alone is insufficient for language acquisition, termed "the poverty of the stimulus" argument. Chomsky proclaimed that a specific innate mechanism must be present, which he termed the language acquisition device. This device, according to Chomsky, programs every child's brain with "universal grammar" and with it comes the potential to learn any language, by extracting syntactic patterns from adults' speech (Chomsky, 1972). When Chomsky refers to universal grammar, he makes a case for explaining the similarities between the thousands of languages on earth. For example, recursion – where thoughts are embedded in sentences or verb-subject-object orders are present in all languages studied (Pinker 2002).

In opposition to Chomsky's universal grammar theory, Karmiloff-Smith (2010) argued that despite the discovery of regional specialised brain areas for language processing (e.g., Broca's and Wernicke's areas), these areas can develop in response to experience and are not necessarily innate. Furthermore, universal grammar cannot explain individual differences in language acquisition (Kidd, Donnelly, & Christiansen, 2018). Specifically, if experience acts upon and selects the language-specific (e.g., English) required components to use from a universal grammar, then we would expect to see a bimodal distribution of test performance of this syntactic structure in the population. Either the language-specific component relevant to the task has been switched on resulting in above-chance performance, or it hasn't resulting in at-chance performance, whilst any other difference between children would be due to error variance. However, the distribution of language development at any age is unimodal with much variation which supports a usage-based approach to language acquisition (Kidd et al., 2018; Lieven, 2016).

In summary, usage-based theory proposes that linguistic input is imperative for language learning, a notion supported by other social learning theories (Bronfenbrenner, 2005; Kuhl, 2007; Vygotsky, 1978) and is most akin to the findings within this thesis.

1.1.4 Behavioural Genetics

Children's linguistic, cognitive and behavioural development involves an interplay between genes and the environment (Knopik et al., 2017; Rahul & Ponniah, 2019) with complex human traits being both polygenic and polyenvironmental (i.e., influenced by multiple genetic variants and environmental elements; Barlow, 2019). The influence of genes, the environment and gene–environment correlations (rGE) to child development can be disentangled somewhat by studies that employ twin designs. Gene–environment correlations refer to the extent to which genetic and environmental variance in a trait overlap

(Barlow, 2019). Three types of rGE have been proposed, active, passive and evocative.

Active rGE refer to the notion that individuals are not passive recipients of their environment, but actively seek out, create and manipulate environments based on their genetically determined predispositions. The environment in turn then reinforces this behaviour, for example a child genetically predisposed to internalising behaviour will withdraw from social interactions due to anxiety and thus they are more likely to be left alone which reinforces their own solitude. In contrast, gene environment correlations can occur through an inactive process in the form of passive rGE, whereby an association between the environment and the individual can be partly explained by shared DNA with the person providing the environment. An example would be, a child with a genetic propensity for externalising behaviour may receive more hostile and aggressive reactions from their parent, however the parent and child share some genes for aggressive behaviour and as such the environment is an artefact of these shared genetic predispositions. Evocative rGE refers to the individuals evoking different environmental responses based on their inherited predispositions. For example, a happy child is likely to evoke more joy from others.

A meta-analysis reviewed 32 studies of child twins to assess if there is a child effect on parenting behaviour which represents evocative gene environment correlations (Avinun & Knafo, 2014). The authors reported that heritability estimates accounted for 23% of the variance in parenting behaviours which confirms that a child’s genetic make-up evokes behaviour from their parents. However, this association was moderated by assessment method: when parenting was assessed by observation, instead of parent/child report, the effect of child genotype on parenting was non-significant. The meta-analysis also reported that the shared, and non-shared environment explained 43% and 34% of the variance respectively, suggesting substantial consistency in parenting behaviours but also considerable differential treatment of twins (i.e., the non-shared environment). The non-shared environment refers to experiences which are unique to the individual, such as injuries or diseases (Barlow, 2019). The shared environment differed by assessment method with parent and observer reports showing higher values than child reports, such that parents reported treating their twins more similarly than the children perceived they did. However, these studies assessed older children, and the effect of the shared environment decreases with age as children become more independent (Avinun & Knafo, 2014). The non-shared environment also contains measurement error and possible common method variance as the same parent reported on both their twins, parents reported that they treat their twins more alike (i.e., lower non-shared environment variance) that the children or an observer does. Nevertheless, evocative gene environment correlations suggest that parent-child relationships are bidirectional (Avinun & Knafo, 2014; Oliver & Pike, 2018).

Limitations of behavioural genetic studies. In twin studies, any causal environmental factor that effects each twin in an opposite direction will be attributed to the non-shared pool of variance, even though objectively both twins are exposed to that factor they are just differentially affected by it (Barlow, 2019). The perception of the environment is often subjective, for example reports of parents' warmth and negativity elicited from parents, children and observers only weakly to moderately correlated (Feinberg, Neiderhiser, Howe, & Hetherington, 2001), and results in twin studies are confounded by assessment method (Avinun & Knafo, 2014). Some researchers argue that the environmental influence of parenting on typically developing children's outcomes is negligible (Plomin, 2018). However, this may be an artefact of the lack of detailed assessments in twin studies because of the extensive sample sizes needed, the method of assessment is dependent on resources available (Oliver, 2020).

In summary, behavioural genetics studies provide evidence that a child's development is unique, not only because of the genes they possess but also because of the environment that they experience, which is itself moulded by the child's genome. This thesis aims to assess the environmental contribution to children's outcomes. Any associations found are likely to be confounded by genetic effects and gene environment correlations, nevertheless, it is important to investigate which aspects of the environment contribute to child outcomes because they are malleable and thus may be targeted in interventions.

1.1.5 The Environmental and Age Specificity Hypotheses

Another theoretical perspective of child development is the environmental and age specificity hypotheses. Early life home environments comprise a multitude of factors that may influence child development. It is possible that a child outcome may only be associated with a specific environmental factor, for example, children's behaviour may only be predicted by parenting and not the language input they are exposed to. Conversely, a child outcome may be influenced by multiple environmental factors. For example, children's behaviour could be influenced by parenting, parental literacy behaviours and all characteristics of adult speech.

The notion that different aspects of child development have unique environmental predictors is termed the environmental specificity hypothesis

(Wachs & Gruen, 1982). By comparison, the global hypothesis assumes that environments are either good or bad for nurturing all aspects of children's development (Wachs & Gruen, 1982). The difference between these two frameworks is exemplified by Hoff's (2003) study comparing children's language development in families of mid and high socioeconomic status (SES). Within a global hypothesis framework, we would expect all environmental measures that differed between the two SES groups to predict children's language development. However, Hoff (2003) found that only particular properties of language input that differed as a function of SES predicted children's language development, which supports the environmental specificity hypothesis. By comparison, other studies of child development support the global hypothesis, for example, Pianta, Nimetz and Bennett (1997) reported that parenting was associated with children's cognitive ability and their behaviour.

This thesis investigated which properties of language input (i.e., the quantity, lexical diversity and vocabulary sophistication) were most salient for children's language (i.e., their lexical diversity and vocabulary sophistication), non-verbal cognitive development, and also their behavioural responses. In addition, parents' literacy behaviours and beliefs, and their parenting behaviours were assessed to test their unique contributions to the child outcome variables. The aim was to conduct multivariate analysis on measures of the home environment to elucidate the differential effects of these predictors on children's outcomes.

Coupled with the environmental specificity hypothesis is the age specificity hypothesis, which suggests that different properties of the environment may be more influential at different children's ages (Wachs & Gruen 1982). To test this hypothesis, paper 3 in this thesis investigated the differential effects of children's age on associations between properties of language input and children's linguistic and cognitive outcomes.

In summary, the theoretical frames described above suggest that the home environment is the most prominent source of influential interactions for child development. Furthermore, the family is an inter-dependent system and thus both parents should be considered when assessing the influence of the home environment on child outcomes. Although both genetic and environmental influences are thought to contribute to child development, it is beyond the scope of the current thesis to assess genetic contributions and thus the focus is on the environment. This thesis will investigate which environmental predictors are most salient for different aspects of child development using substantial naturalistic observations.

1.2 Why Naturalistic Observations of the Home Environment are Important

To understand the impact of the home environment on children's outcomes, it is imperative that observations of these environments capture typical family functioning. Naturalistic observations, where the participants are unaware of being observed, allow researchers to glean insights into behaviours that occur in real life and thus inform our understanding of relations between different aspects of adult-child interactions. In addition, naturalistic observations that employ digital technologies allow for extensive recording durations and large sample sizes, which increases both power and representativeness.

The naturalistic studies of early life home environments that have been conducted to date rely on short observations with small samples sizes, and they were mainly based in the USA (Huttenlocher, Vasilyeva, Waterfall, Vevea, & Hedges, 2007; Huttenlocher, Waterfall, Vasilyeva, Vevea, & Hedges, 2010; Ramírez-Esparza et al. 2014; Rowe, 2008). Therefore, it is important to utilise novel digital technologies to confirm and extend our knowledge about the environmental influences on child outcomes in a British population.

1.3 Sample

All three papers in this thesis were based on analyses of the same sample, which included 107 typically developing children (mean age in years across recordings = 2.77, *SD* = 0.55, range = 2.03 to 3.99), and their families. All families were monolingual English speaking and had completed 3 days of audio-recordings of their home environments for at least 5 hours per day (*M* = 15.06, *SD* = 1.87). In addition, 105 mothers (mean age in years = 37.11, *SD* = 4.56, range = 22.48 to 51.57) and 73 fathers (mean age = 39.49, *SD* = 5.16, range = 25.24 to 55.09) also completed an online survey (details included in studies' descriptions). Of the 107 children, almost half were girls (48%) and more than half had at least one sibling that lived in the same household (54%).

The vast majority of parents had been born in Britain and were native speakers of English (86% and 99%, respectively). On average, parents had lived in the United Kingdom for 33.42 years (*SD* = 10.92, range = 0 to 55). Most of the mothers were employed part-time (58); 28 were full-time parents; 11 were in full-time employment; 4 identified as students, and 4 were on maternity leave. Of the fathers, 59 were in full-time and 10 in part-time employment; 4 were full-time parents. Most parents in the sample held university degrees (86% of mothers and

78% of fathers) and were married co-parents (96%), most whom had been living together for 4 or more years (92%). The families were on average of high SES although there was variation in sociodemographic background.

The study materials were hand delivered to each family and collected in person once the audio-recordings and cognitive testing booklet were completed. The data was then prepared for transcription and analysis.

1.4 LENA Technology

The Language Environment Analysis (LENA) system consists of digital language processors (DLPs) and accompanying LENA pro software (LENA Research Foundation, 2012). The DLPs are small, lightweight audio-recorders that compress audio files allowing space for the acoustic environment to be recorded continuously for up to 16 hours. LENA DLPs were worn by the study children in the front pockets of custom-made clothing and therefore did not restrict children's daily activities. All sounds within a six-foot radius of the DLPs were recorded.

The LENA pro software automatically extracted various language markers from the audio data such as the number of adult words spoken within the study child's earshot. LENA adult word count estimates encompass all words spoken by any adult, not just the primary caregiver, and therefore capture an accurate representation of children's natural language environments (Ramírez-Esparza, García-Sierra, & Kuhl, 2014; Sperry, Sperry, & Miller, 2019). Digital technologies such as LENA dramatically reduce researchers time in collecting and processing data which allows for comprehensive observations to be taken. Moreover, the size and mobility of the LENA DLPs means that home environments can be observed unobtrusively, and the data retrieved encapsulates natural interactions from a child's perspective.

1.5 Summary – Paper 1

A Naturalistic Home Observational Approach to Children's Language, Cognition, and Behaviour

Paper 1 was previously published: d'Apice, K., Latham, R. M., & von Stumm, S. (2019). A Naturalistic Home Observational Approach to Children's Language, Cognition, and Behavior. *Developmental Psychology, 55*(7), 1414-1427. https://doi.org/10.1037/dev0000733. The full study and supplemental materials are detailed in Chapters 2 and 3.

This study aimed to investigate markers of the home environment, using naturalistic observations, and test which of these were associated with children's linguistic, cognitive and behavioural development. This study sought to address the following research question; how are the quantity and lexical diversity of adult speech, and parenting behaviours associated with children's language, cognitive and behavioural outcomes?

The quantity of adult speech was automatically extracted from audio-recordings of the home environment by LENA pro software (LENA Research Foundation, 2012). In addition, two 5-minute excerpts per day (i.e., 30 minutes across 3 days) which showed the most adult-child conversational interactions in LENA, were transcribed. From the transcripts, I computed the lexical diversity of all adult and child speech within each family. The transcripts were also used to assess children's and parents' behaviours via a coding system based on audible behaviours. In addition, the parents administered a cognitive testing booklet to their child and reported on their child's abilities, family characteristics and demographics via an online survey.

The key finding from this study was that the quantity of adult speech to which children are exposed varied as much within as between families across hours and days (intraclass correlation = .14 and .47 respectively). This means that the amount of hourly adult talk to which children are exposed varies more within their own family than between families. Almost half of the variance in the quantity of adult speech across days occurred within, and half between families. How language input changes over time, both across hours and days, is rarely studied (Tamis-LeMonda, Kuchirko, Luo, Escobar, & Bornstein, 2017). Indeed, to my knowledge only 3 studies report the stability of adult word counts across days (Hart & Risley, 1995; Gilkerson et al., 2017; Greenwood, Thiemann-Bourque, Walker, Buzhardt, & Gilkerson, 2011). Hart and Risley (1995; pp 195 - 196) stated that family talk was stable over the 2.5 years of the study. They reported that the amount of talk did change over the years however it was relative to other families in the study. Likewise, Greenwood et al. (2011) stated that adult word counts between families were stable over the 10 months of their study, yet they only reported this data for 2 of the 30 families. By comparison, Gilkerson et al. (2017) report a within-family correlation of .66 between adult word counts on consecutive days, however this fell to around .40 when the time span between observations increased to between 4 and 16 weeks. Therefore, my finding of the extreme within-family variability in adult speech in a relatively large sample, contributes to our knowledge about the stability of children's language environments.

Another important finding from this study was that the quantity of adult speech explained 15% of the variance in children's cognitive testing booklet scores. In addition, adults' lexical diversity accounted for 18% of the variance in children's lexical diversity. Furthermore, 6% of the variance in children's externalising behaviours was explained by their parents' positive behaviours.

In conclusion, this study revealed that language environments are important and dynamic. Therefore, we need comprehensive observations to ensure valid and accurate assessments of language environments. Digital technologies such as LENA afford the possibility of capturing such observations unobtrusively. Furthermore, audio-recordings are a useful tool for documenting natural parent and child behaviours.

1.6 Summary – Paper 2

The Role of Spoken Language and Literacy Exposure for Cognitive and Language Outcomes in Children

Paper 2 has recently been published by the *Scientific Studies of Reading*: d'Apice, K., & von Stumm, S. (2020). The Role of Spoken Language and Literacy Exposure for Cognitive and Language Outcomes in Children. *Scientific Studies of Reading, 24*(2), 108-122. https://doi.org/10.1080/10888438.2019.1641505. The manuscript and supplemental materials are presented in Chapters 4 and 5.

This study aimed to evaluate the relative contributions of naturalistic adult speech and parents' literacy behaviours to children's cognitive and language outcomes. This study sought to address the following research question; how does the quantity and lexical diversity of adult speech, and parental literacy behaviours compare in their association with children's language and cognitive outcomes?

In addition to the language and cognitive markers detailed in study 1, this study also included measures of parents' literacy behaviours. Taking a more comprehensive assessment approach than previous studies, literacy behaviours were indexed by parents' literacy activities, practices and beliefs that they reported on via an online survey.

The key finding from this study was that parents' literacy behaviours accounted for 5% of the variance in children's cognitive ability, independent of the quantity and lexical diversity of adult language that children heard in the family home. This finding suggests that interventions aimed at improving parents' literacy activities, practices and also beliefs may be beneficial for children's cognitive development. In addition, parental literacy behaviours correlated .33 with the quantity of adult words, suggesting that parents who expose children to more adult words also engage in more literacy behaviours and hold stronger literacy beliefs.

1.7 Summary – Paper 3

Does Age Moderate the Influence of Early Life Language Experiences? A Naturalistic Home Observation Study

Paper 3 was submitted to the *Journal of Cognition and Development* for publication on 11th April 2020. The full study is detailed in Chapter 6. https://psyarxiv.com/jr4by/

This study aimed to investigate differential children's age effects on the associations between characteristics of adult speech and children's linguistic and cognitive outcomes. The research question that this study sought to answer was; does children's age moderate the association between the quantity, lexical diversity or vocabulary sophistication of adult spoken language and children's language and cognitive outcomes?

The data obtained in study 1 was supplemented by an additional language marker; vocabulary sophistication (i.e., the number of rare words). Previous studies suggest that vocabulary sophistication may be a more powerful discriminating component of language input related to child vocabulary development than either the quantity or lexical diversity of adult speech (Rowe, 2012; Weizman & Snow, 2001). The transcripts from study 1 were used to derive the vocabulary sophistication measures: First, all non-dictionary words were omitted from the transcripts including proper names of family members, friends and pets. Second, all words on the Dale-Chall word list (Chall & Dale, 1995; Dale & Chall, 1948), a 3,000-word list of the most common words known by fourth graders, and their inflected forms were omitted from the transcripts. The remaining words were considered to be sophisticated or rare words. Adults' vocabulary sophistication was calculated by dividing the number of sophisticated word types (i.e., number of different sophisticated words) by the number of word types which controlled for volubility. Likewise, children's vocabulary sophistication was computed as the portion of sophisticated word types from total word types. This method has been used in previous studies (Rowe, 2012; Weizman & Snow, 2001).

A series of regression models with the interaction term (i.e., children's age x early life language experience) were generated. Adults' vocabulary sophistication explained 28% of the variance in children's vocabulary sophistication, but there was no interaction with children's age. Likewise, children's age did not moderate associations between the quantity or lexical diversity of adult speech and children's outcomes.

In conclusion, findings suggest that associations between specific characteristics of adult speech, and children's language and cognitive outcomes do not vary meaningfully across children's age. This means that within the child age range studied (i.e., 2 years) there was no evidence to support the *age specificity hypothesis*. Due to natural variation in children's language abilities, it may be that children's developmental age is a moderator rather than their chronological age, as all children progress at different rates. Therefore, studies which take a more individualised perspective, using more sophisticated statistical analyses such as individual growth modelling, may find that specific characteristics of adult speech are more important as children develop their linguistic skills.

1.8 Coherent Body of Work

Overall, this thesis aimed to investigate which characteristics of the home environment are most important for different aspects of children's development, and whether children's age moderated these influences. This research was underpinned by the *environmental specificity hypothesis* framework and so brought together multiple markers of the home environment and demarcated the importance of each of these for children's developmental outcomes. Therefore, Paper 1 was a comprehensive investigation into associations between aspects of adult speech and parenting behaviours, and children's linguistic, cognitive and behavioural outcomes. An additional marker of the home environment, parents' literacy behaviours and beliefs, was introduced in Paper 2 to investigate whether it influenced children's outcomes independent of the language they heard in the family home. Paper 3 was based upon the *age specificity hypothesis* and so tested if the associations between the characteristics of adult speech and children's outcomes found in Paper 1 were moderated by children's age.

This thesis provides empirical evidence that specific aspects of the home environment are differentially associated with children's developmental outcomes in support of the *environmental specificity hypothesis*. No evidence was found that children's age moderated these associations and therefore I cannot confirm the *age specificity hypothesis*. In addition, empirical evidence of the importance of language input for children's language acquisition was found. Thus, my work supports the *usage-based* theory of language acquisition which posits that behaviour results from learning and therefore language skills develop from observing and listening to an external model of language (Langacker, 1987; Tomasello, 2003).

1.9 Original Contribution

This thesis provides an original contribution to the field of developmental research in several ways. First, this thesis explored associations between early life experiences of language and parenting on children's language, cognitive, and behavioural differences using naturalistic observations of 107 families. Therefore, this is the largest naturalistic home observational study of British families to date, which gives us unprecedented insight into English children's home environments. Previous LENA studies observed families in the USA, Canada, France, China and South Korea (see Wang et al.'s 2017 review). We cannot assume that family talk in other countries is generalisable to British populations because there are cultural differences to consider.

Second, my studies are the first to assess the lexical diversity and vocabulary sophistication of naturalistic speech collected unobtrusively by LENA audio-recorders. Previous LENA studies relied solely on automated language measures, and therefore my research provides a more comprehensive assessment of children's language environments. Third, my method for assessing parenting behaviours via audio-recordings is also novel and free from observer biases, thus retaining high ecological validity. To the best of my knowledge, only one previous study used audio-recording equipment to document naturalistic parenting behaviours over time in the family home (Holden, Williamson & Holland, 2014). However, this study assessed parental incidences of corporal punishment (e.g., slapping or hitting) in a small sample of 33 families. By comparison, my method applied a psychometric assessment of parents' behaviours.

Fourth, the key finding from Paper 1 of the extreme within-family variability in children's language exposure, was not previously recognised, and therefore makes a theoretical contribution to the field of child development, with implications for how we assess language input. My final contribution is the novel finding from Paper 2, that parents' literacy behaviours explain a significant amount of variance in children's cognitive abilities independent of the adult speech they hear in the family home.

1.10 A Note on the Role of SES in Studies on Home Language Environments.

There is an abundance of studies that have shown adult language input and child language differ by SES (Hoff, 2003; McGillion et al., 2017; Pace et al., 2017; Rowe, 2008). However, SES effects are compounded by a variety of third factors, such as access to resources, family stress levels and mental health. In addition to these socio-economic factors, aspects of caregiver language input such as the use of prohibitions, directives and encouragements differ by SES (Hart & Risley, 1995). Therefore, assessing adult language input within the relatively homogenous SES group in my sample, reduces variability in these confounding factors.

In addition, there is considerable variation in language input *within* SES groups (Sperry et al., 2019; Weisleder & Fernald, 2013) and therefore, it is important to investigate the impact of language input within these SES groups to better understand how language input relates to individual differences in language acquisition. It has been suggested that the focus on group-based differences in language acquisition, such as SES-related differences, have masked the importance of individual differences (Kidd et al., 2018). Moreover, my finding from Paper 1 that considerable variation in language input occurs not only within an SES group but also *within* families, highlights the necessity to unpick how adult language input influences children's outcomes regardless of SES group.

1.11 Conclusion

In conclusion, my findings that specific aspects of the home environment are differentially associated with children's outcomes suggest that targeted interventions may yield improvements in particular aspects of child development. Given that family homes are multifaceted, dynamic environments we can utilise digital technologies to conduct comprehensive observations which are imperative to accurately assess these environments. Future studies that undertake a longitudinal and individualised approach to child development could further our understanding of the specific factors that enable each individual child to flourish over time.

1.12 References

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2 Paper 1: A Naturalistic Home Observational Approach to Children's Language, Cognition, and Behaviour

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2.1 Abstract

Although early life experiences of language and parenting are critical for children's development, large home observation studies of both domains are scarce in the psychological literature, presumably because of their considerable costs to the participants and researchers. Here, we used digital audio-recorders to unobtrusively observe 107 children, aged 2.03 to 3.99 years (M = 2.77, SD = 0.55), and their families over 3 days (M = 15.06 hr per day, SD = 1.87). The recording software estimated the total number of words that a child heard over the course of a day. In addition, we transcribed six 5-min excerpts per family (i.e., 30 min overall) to extract estimates of children's and their parents' lexical diversity, positive and critical parenting, and children's internalising and externalising behaviours. We found that home language input (i.e., number of words and lexical diversity) was positively associated with children's cognitive ability and lexical diversity but not with their behaviours. In addition, we observed that home language input varied as much within as between families across days (intraclass correlation = .47). By comparison, parenting predicted children's behavioural outcomes but was not related to their cognitive or lexical ability. Overall, our findings suggest that home language input affects child development in cognition and language, while positive parenting informs their behavioural development. Furthermore, we demonstrated that digital audio-recordings are useful tools for home observation studies that seek to disentangle the complex relationships between early life home environments and child development.

2.2 Introduction

Home language input and parenting behaviours are two key characteristics of the family home environment that shape children's early life experiences (Hart & Risley, 1995; Stein et al., 2013), although they are typically studied in independent research contexts and samples. Home language input refers to the quantity and quality of children's exposure to adult speech in the family home, including speech from parents and other caregivers. Home language input has been previously associated with the development of children's verbal and cognitive abilities (Hart & Risley, 1995; Hoff, 2003; Huttenlocher, Waterfall, Vasilyeva, Vevea, & Hedges, 2010). Likewise, parenting behaviours, such as responsiveness, warmth, and stimulation, have been shown to be associated with children's cognitive and also their behavioural development (Merz et al., 2016; Stein et al., 2013). However, these earlier findings about the relationship between parental input and children's development were based on either brief home observations that lasted no longer than 1 hr or on observations of instructed interactions between parents and children, often in laboratory settings. The reason for the scarcity of extensive home observation studies is their extremely high costs (Mehl, 2017): Trained researchers had to visit each family home, carry out observations—often using handheld audio-recorders (e.g., Hart & Risley, 1995), transcribe and code observations, which typically takes eight times as long as the actual recording duration, and conduct reliability tests on the transcripts and coding (Margolin et al., 1998). As a result, studies that relied on home observations typically tested small samples with 50 and fewer families, who were recorded for relatively short time periods, ranging from 1.5 min to 1.5 hr at a time (Hart & Risley, 1995; Rowe, 2012; Wells, 1985; Table 1.1). Furthermore, the physical presence of a researcher to operate the audio or video equipment may trigger observer reactivity, with the recordings not being truly representative of families' natural language and behaviour (Dudley-Marling & Lucas, 2009; Gardner, 2000).

Here, we overcome these limitations of traditional home observation studies with a digital recording technology, known as the Language Environment Analysis (LENA) system (LENA Research Foundation, 2012). The LENA system is comprised of digital language processors (DLPs) that are worn in custom-made children's clothing and record all sounds within a 6-ft radius. This technology facilitated observing language and parenting in 107 families across 3 full days, which is the largest family home observational study to date.

Table 1.1

Home Observational Studies of Families' Language Use

Authors	Sample *n*	Child age at time 1	Assessment method	Assessment duration	Mean adult word count estimates (*SD*) range
Christakis et al., 2009	329	2 to 48 months	LENA audio-recordings	Daylong once a month for an average of 8 months (range, 1 to 24 months)	Per day **12,976** (6,051)
Gilkerson et al., 2017	82	36 months	LENA audio-recordings	12 hours	Per day **12,990** (6,025)
Greenwood et al., 2011	30	12 to 21 months	LENA audio-recordings	12 hours a day, 1 to 3 times a week, for 10 months	Per day **13,142** (5,562), range 631 to 36,563
Hall et al., 1984	39	54 to 60 months	Audio-recordings	10 x 15 minutes x 2 days = 5 hours in total per child	Per hour for middle-class **2,383**; working-class **1,840**
Hart et al., 1995	42	7 to 12 months	Audio-recordings	60 minutes each month, for 23 to 30 months (mean = 28 months)	Per hour for professionals **2,153**, range 1,019 to 3,504; working-class **1,251** range 143 to 3,618; welfare **616** range 231 to 947
Hoff, 2003	63	16 to 31 months	Video recordings	43 minutes at time 1; no time estimate given for follow-up assessment 10 weeks later	Per 43 minutes for high SES **2,165.12** (833); mid SES **1,570.40** (538)
Huttenlocher et al., 2007[a]	50	14 months	Video recordings	90 minutes every four months x 4 to 5 visits	Per 90 minutes, 20 mean estimates reported, range 1,563 to 4,093
Pan et al., 2005[b]	108	14 months	Video recordings	3 x 10 minutes, 10 to 12 months apart	Per 10 minutes, 3 mean estimates reported, range 505 to 638
Ramírez-Esparza et al., 2014	26	10 to 24 months	LENA audio-recordings	8 hours a day, for 4 consecutive days	Across 4 days **31,111.51** (9,886), range 16,591 to 56,224
Rowe, 2008	47	31 months	Video recordings	90 minutes	Per 90 minutes **3,768** (1,936), range 696 to 7,673
Rowe, 2012	50	18 months	Video recordings	90 minutes, once a year for 3 years	Per 90 minutes **3,523** (1,951), range 360 to 9,227
Zimmerman et al., 2009	275	2 to 48 months	LENA audio-recordings	12 hours a day, once a month for 6 months	Per day **12,800** (4,400)

Note. Home observational studies were identified that included a monolingual English child aged 60 months or under, used unstructured activities and reported adult word counts. Average adult word count estimates (i.e., means) are shown in bold, and refer to periods of observations reported in original papers (e.g., per day). SDs (shown in parentheses) and range of adult word counts are reported where available. In papers where mean word counts were reported only for subsamples (e.g., working-class), the table lists the available estimates for all groups. [a] Huttenlocher et al. (2007) reported adult word counts for 5 child ages (14-, 18-, 22-, 26- and 30-months) and 4 education classes, [b] Pan et al. (2005) reported adult word counts for 3 child ages (14-, 24- and 36-months), to maintain accessibility of the table these are not reported in full.

Quantity of Home Language Input

The quantity of adult speech (i.e., the number of words spoken) that children experience is one important factor in their own language acquisition (Hoff, 2003; Rowe, 2012). Table 1.1 provides an exhaustive list of studies that were (a) observational; (b) conducted in the family home; (c) collected naturalistic observations, without instructed activities or play; (d) with monolingual English children aged up to 5 years; and (e) reported adult word counts. Overall, seven studies relied on traditional video- (*n* = 5) and audio-recordings (*n* = 2), while five studies used LENA's digital audio-recordings. Across studies, sample sizes varied from 26 to 329, and recording durations ranged from 10 min to 12 hr per observation. Average reported adult word counts per hour ranged from 972 to 3,021 words. In addition, a public repository of day-long naturalistic audio-recordings exists (Home Bank; Van-dam et al., 2015), as does an extensive corpus of early language experience from a single child (Human Speechome Project; Roy, Frank, DeCamp, Miller, & Roy, 2015), which are not reviewed here.

The best-known study on the effect of the linguistic home environment for child development is Hart and Risley's (1995), in which trained researchers visited the homes of 42 families once a month for 28 months, starting when the focal child was aged 9 months. The families were audio-recorded, with a researcher following the study child for 1 hr per month at a time that was convenient for and selected by the parents, using a hand-held tape recorder and microphone. Data from the hour-long recordings was then extrapolated under the assumption that verbal communication within families is fairly consistent across 14 hr per day. Based on these estimates, Hart and Risley (1995) proposed that children from welfare families hear just over 8,600 words per day, while working class children hear 17,500 words and high-class children over 30,000. If we translate these daily estimates into yearly ones, the so-called "30 million word gap" emerges (Hart & Risley, 1995; Radesky, Carta, & Bair-Merritt, 2016): By the age of 4 years, children from welfare families hear just under 13 million words from adults, while high socioeconomic status (SES) children hear over 52 million words during the same time period. Although associations between family background and home language input had also been reported elsewhere (e.g., Hall, Nagy, & Linn, 1984), the dramatic disparities in adult word counts documented by Hart and Risley (1995) carried the gravitas to reach the general public, as well as clinicians, charities, and teachers, and to inspire numerous interventions (e.g., Radesky et al., 2016). However, an attempt to replicate Hart and Risley's findings of the vast differences in language environments by SES group was not successful and instead highlighted the large variation in adult word counts within SES groups (Sperry, Sperry, & Miller, 2019).

More recent studies have used the LENA system to observe language in samples of 30 to 329 American families (Christakis et al., 2009; Gilkerson et al., 2017; Greenwood, Thiemann-Bourque, Walker, Buzhardt, & Gilkerson, 2011; Zimmerman et al., 2009), who were representative in SES of the United States, specifically of the population in Kansas, where Hart and Risley (1995) had also collected their data. The families' word counts ranged from 12,800 to 13,142 words over the course of a 12-hr day (Christakis et al., 2009; Gilkerson et al., 2017; Greenwood et al., 2011; Zimmerman et al., 2009). These figures suggest that Hart and Risley (1995) overestimated the quantity of daily adult speech that children experience in the family home, if we assume that family language interactions have not substantially changed since the 1980s. Comparable data from other countries, including the United Kingdom, are currently not available to clarify how much adult speech children actually experience.

Previous studies have concluded that the quantity of adult speech that children are exposed to is positively associated with their own language skills. For example, Hart and Risley (1995) found that adult word counts per hour correlated .62 with the number of different words children uttered per hour at 34 to 36 months of age. Corroborating this finding, Hoff (2003) reported a correlation of .21 between the quantity of mothers' and children's words, after adjusting for children's previous vocabulary, by analysing video-recordings of 63 mother– child dyads during their morning routines when children were aged 16 to 31 months. In another set of video-recordings of daily interactions in 50 families, Rowe (2012) reported correlations of .33, .42, and .37 between the quantity of parents' words and children's vocabulary, assessed by the Peabody Picture Vocabulary Test (PPVT-III; Dunn & Dunn, 1997), at the children's respective ages of 30, 42, and 54 months. The results of studies using the LENA system also support the benefits of the quantity of adult speech for children's linguistic development. In a sample of 275 families with children aged 2 to 24 months, who were audio-recorded for 12 hr once a month for 6 months, Zimmerman et al. (2009) found that a 1,000-word increase in adult speech was associated with a 44% gain in children's language ability, assessed by the Preschool Language Scale (PLS-4; Zimmerman, Steiner, & Pond, 2002). By contrast, Greenwood and colleagues (2011) failed to detect a significant correlation between the quantity of parents' and children's words in a much smaller sample of 30 toddlers aged 12 to 20 months. Likewise, a study involving 10-min video-recordings of 108 mothers with children aged 14 months, observed once annually for 3 years, did not find an association between maternal word quantity and children's growth in the number of different words spoken (Pan, Rowe, Singer, & Snow, 2005), suggesting that the quality rather than the quantity of language input may be more important for children's language growth. This notion was corroborated in a sample of 60 children aged 24 months; the quality of communication accounted for 16.4% whereas the quantity of language input only accounted for 1% of the variance in children's language development 1 year later (Hirsh-Pasek et al., 2015).

The quantity of adult speech is thought to not only benefit children's verbal development but also that of other cognitive abilities. For example, Hart and Risley (1995) reported a positive association between the quantity of adult speech and children's IQ, assessed by the Stanford-Binet Intelligence Scale at 36 months of age. In another study of 26 preterm infants, differences in the quantity of adult speech that the infants experienced at 36 weeks accounted for 26% of the variance in their cognitive scores 10 months later (Caskey, Stephens, Tucker, & Vohr, 2014). Overall, however, the empirical evidence for the link between the quantity of adult speech and children's cognitive abilities is limited and at times contradictory (e.g., Greenwood et al., 2011).

Quality of Home Language Input

The quality of language refers to the diversity, complexity, and richness of speech and is marked by lexical diversity that reflects the number of different words used in a sample of speech—so-called "word types." Words that are morphologically inflected variants (e.g., car and cars, run and running) are considered to be the same word type, whereas different words for the same object (e.g., bike and bicycle) are treated as different word types (Pan et al., 2005). Other measures of language quality include word sophistication (e.g., rarity of words), word-classes (e.g., verbs, adjectives or nouns), syntactical structure, or even intonation and prosody (Head Zauche, Thul, Darcy Mahoney, & Stapel-Wax, 2016; Malvern, Richards, Chipere, & Durán, 2004; Rowe, 2012). However, lexical diversity is the most valid marker of children's spoken language ability, especially in the context of naturalistic home observations (Durán, Malvern, Richards, & Chipere, 2004; Lai & Schwanenflugel, 2016).

Previous studies suggest that the exposure to lexically diverse adult speech is an important determinant of children's language and cognitive outcomes (Pan et al., 2005; Rowe, 2012). Rowe (2008) video-recorded naturalistic interactions of 47 parent– child dyads at children's age of 30 months. A composite of parental speech, including word counts, word types, mean length of utterance, proportion of directive utterances and D scores, predicted gains in children's vocabulary size over a 12-month period, accounting for 9.5% of the variance. Huttenlocher et al. (2010) corroborated this finding when they observed 47 families in the home environment for 90 min every 4 months for a total of nine visits that commenced when the child was 14 months old. They concluded that caregivers' word types predicted children's word types 4 months later, although they did not report a standard effect size to make the magnitude of their results comparable. Likewise, a recent integrated review concluded that adult lexical diversity was significantly associated with children's language skills across five prospective cohort studies, but no effect sizes were reported (Head Zauche et al., 2016).

With regard to children's cognitive outcomes other than language, parental lexical diversity has been associated with children's IQ (Hart & Risley, 1995). Substantiating this finding, as part of a larger Family Life Project, researchers measured the lexical diversity of 1,292 mothers during 10-min home observations reading with their children (Burchinal, Vernon-Feagans, Cox, & Key Family Life Project Investigators, 2008). Maternal lexical diversity when children were aged 6 months correlated .16 with children's cognitive skills assessed 9 months later with the Mental Developmental Index (MDI) of Bayley Scales of Infant Development (BSID-II; Bayley, 1993; Burchinal et al., 2008). Overall, previous studies reported positive associations between the lexical diversity of adult speech and children's cognitive and lexical outcomes, with effect sizes that range from small to modest.

Early Life Parenting

Parenting is the process of nurturing a child's socioemotional, physical, and cognitive development from birth onward (Belsky, 1984; Brooks, 2012). Positive parenting is characterized by warm, responsive, and encouraging behaviours (Bennetts, Mensah, Westrupp, Hackworth, & Reilly, 2016), while critical parenting describes an independent second dimension that is defined by negative attitudes and feedback to the child, expressions of disapproval and even threatening behaviour (Sher-Censor, Shulman, & Cohen, 2018). Through the interactions with their parents, children are thought to develop their own behavioural styles, which are typically differentiated into internalising behaviours that refer to symptoms of depression, anxiety, social withdrawal, and psycho-somatic problems, and externalising behaviours that imply anger, frustration, irritability, and aggression (Achenbach, 1991; Eisenberg et al., 2001).

Positive parenting has been shown to benefit children's adjustment in observational studies of the family home. For example, 320 mother–child dyads were visited at home at 10, 18, and 36 months and assessed for maternal caregiving, which accounted for up to 5% of the variance in children's prosocial behaviour and hyperactivity, and for 9% of the variance in their peer problems (Stein et al., 2013).

Critical parenting has also been shown to be associated with child development, for example it accounted for 9% of the variance in externalising behaviours in 5-min speech samples from 55 mothers and their toddlers aged 19 to 47 months (Sher-Censor et al., 2018). This and other studies in this area relied on parental reports or visiting researchers' reports to assess parenting behaviours (e.g., van Prooijen, Hutteman, Mulder, van Aken, & Laceulle, 2018). We identified only one previous study that used audio-recording equipment to document naturalistic parenting behaviours over time in the family home (Holden, Williamson, & Holland, 2014): In 33 families with a child aged 2 to 5 years, the mother wore a digital voice recorder in a sports pouch that was attached to her upper arm for 4 to 6 consecutive evenings, between 5 p.m. and the child's bedtime (Holden et al., 2014). The recordings (on average 13 hr per family) were coded for parental incidences of corporal punishment (e.g., slapping, hitting) and children's behaviour, for example aggressive transgressions (Holden et al., 2014). The authors found meaningful associations between parenting and children's behaviours, and they concluded that audio-recordings were an effective method for studying family interactions in the home. Accordingly, audio-recordings have also been used to examine the effectiveness of parenting intervention programs (e.g., Johnson, Christensen, & Bellamy, 1976). Within the personality literature, naturalistic audio-recordings have been coded for participants moods (e.g., occurrence of laughing, crying, sighing) which correlated with some aspects of self-reported personality (Mehl, Gosling, & Pennebaker, 2006). Also, Wu, Sheppard, and Mitchell (2016) found that participants made accurate judgments about target person's empathy from audio-recordings, interpreting voice characteristics like tone and pitch. Overall, these findings support the suitability of audio-recordings for collecting naturalistic observations of parenting.

The Current Study

We sought to undertake the largest and most comprehensive investigation to date of how home language input and parenting are related to children's language, cognition, and behaviour. To this end, we used LENA to unobtrusively audio-record 107 children and their families in the home environment over the course of 3 days. Using LENA pro automatic speech processing software, we determined the number of adult spoken words that our sample of British children were exposed to and then assessed the stability of adult speech within-families across hours and days. We also computed D scores to assess the lexical diversity of adults' and children's speech, based on transcriptions of six 5-min excerpts per family, equivalent to 30 min of recordings overall. The D score is based on the probability of introducing new words into progressively longer language samples (see supplemental materials for more information). In contrast to other indices of lexical diversity, for example word types or type-token ratios, D scores are extremely robust against sample size effects and thus constitute reliable markers of lexical diversity (Malvern et al., 2004; McKee, Malvern, & Richards, 2000; Owen & Leonard, 2002). To quantify parenting and children's behavioural outcomes, we coded relevant behaviours from six audio excerpts per family. Previous studies have reported that SES and birth order affect adult speech and children's vocabulary acquisition (Hart & Risley, 1995; Hoff, 2003; Morgan, Farkas, Hillemeier, Hammer, & Maczuga, 2015; Oshima-Takane & Robbins, 2003), which we consider in our analyses although they are not foci.

We hypothesised that adult speech, including the quantity and quality of adult spoken words that children experienced within their families, would be positively associated with children's lexical diversity and cognitive ability. For parenting, we hypothesised that positive parenting behaviours would be associated with lower incidences of children's internalising and externalising behaviours, whereas critical parenting behaviours were likely to coincide with higher occurrences of children's internalising and externalising behaviours. We had no specific hypotheses regarding the predictive validity of SES and birth order for children's behaviours in our sample.

2.3 Method

Sample

Overall, 225 parents (236 children) from Southeast London responded to study advertisements displayed in nurseries (*N* = 59), on Facebook (*N* = 141), through word-of-mouth (*N* = 15) or the authors' lab website (*N* = 10). Of the 210 families (220 children), who met the eligibility criteria (i.e., monolingual English-speaking families with a typically developing child aged 24 to 48 months), 131 parents with 137 children completed a 1hr online survey, and received the study materials, including LENA recording devices, LENA clothing and testing booklets

(Figure 1). Out of these, 107 families completed digital audio-recordings on three different days for more than 5 hr each. In six families, two children (i.e., two fraternal siblings and four twin pairs) participated in the study; to ensure the independence of observations, one sibling was randomly selected to be included in the current analyses. The final analysis sample consisted of 105 mothers (mean age in years 37.11, *SD* = 4.56, range = 22.48 to 51.57), 73 fathers (mean age 39.49, *SD* = 5.16, range = 25.24 to 55.09), and 107 children (51 girls; mean age in years across recordings = 2.77, *SD* = 0.55, range = 2.03 to 3.99). On average, parents had spent 33.42 years in the United Kingdom (*SD* = 10.92, range = 0 to 55), with the vast majority being born in Britain and native speakers of English (86% and 99%, respectively). Of the mothers, 28 were full-time parents; 58 were in part-time and 11 in full-time employment; 4 identified as students, and 4 were on maternity leave. Of the fathers, 59 were in full-time and 10 in part-time employment; 4 were full-time parents. Most parents in the sample held university degrees (86% of mothers and 78% of fathers) and were married co-parents (96%), most whom had been living together for 4 or more years (92%). About half of the children in the sample had siblings that lived in the same household (54%). Although families varied in sociodemographic background, they were on average of high SES.

Procedure

The study entitled "Advancing Data Collection for the Behavioural Sciences: The Practicability of LENA" was approved by the Ethics Committee at Goldsmiths, University of London. Data were collected between November 2014 and August 2016. Parents first completed an online survey to assess sociodemographic background information and various parent and child characteristics.

After parents completed the survey, boxes with study materials were hand-delivered to each family. Each box contained (a) 3 LENA DLPs (details in Measures below), (b) 3 items of LENA clothing, and (c) a Parent Report of Children's Abilities (PARCA) booklet (details in Measures below). Parents conducted the recordings independently on 3 separate days when their child was not attending nursery or any other formal childcare setting. Parents also completed the PARCA booklet with their child in their own time. For their participation, each family was given a child's LENA t-shirt and 79 families also received £50 in cash. Differences in compensation were because of changes in the study's funding, which only became available after the first families had participated.

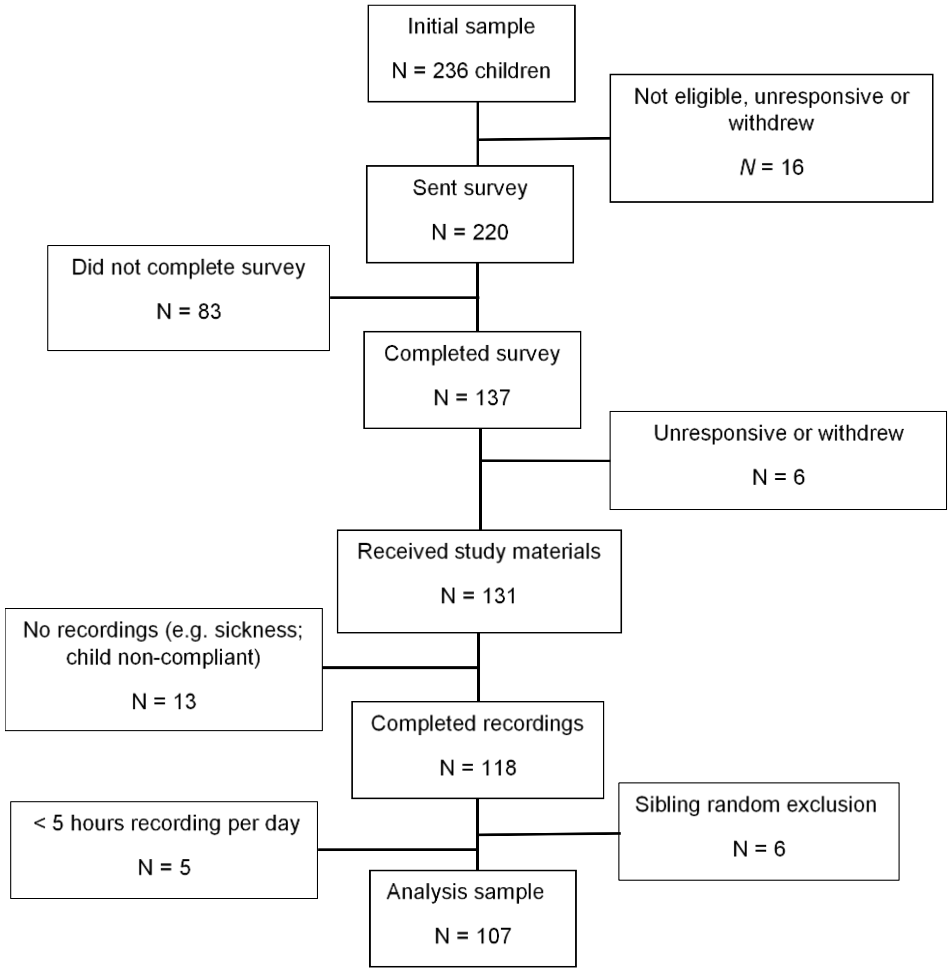

Figure 1. Flowchart of sample selection. Sample counts refer to the number of children.

Measures

Language.

Adult word counts. The LENA DLPs are small, lightweight audio-recorders that record all sounds within a six-foot radius for up to 16 hr per day. Children “wore” the DLPs in the front pockets of specifically manufactured clothes, for example t-shirts and dungarees. Audio-recordings were processed by an ASUS 555LD laptop using the LENA Pro software version V3.4.0 –143, which extracts the number of adult spoken words on each recording day (see supplemental materials; LENA Research Foundation, 2012). LENA software, and human derived adult word counts have previously shown good interrater agreement (Cohen’s *k* 0.65) in a sample of 70 12-hr recordings (Zimmerman et al., 2009).

Lexical diversity. Lexical diversity was extracted based on transcripts of two 5-min recording excerpts per day that registered the highest number of conversational turns in LENA between 8 a.m. and 11 a.m. and between 5 p.m. and 8 p.m. Conversational turns refer to the total number of conversational interactions the child engages in with an adult, in which one speaker initiates and the other responds within 5 seconds. We selected the excerpts with the highest conversational turns counts during the morning and evening, because they offer a rich source of data to compare language and behaviour between families.

Professional typists used the Codes for the Human Analysis of Transcripts (CHAT; MacWhinney, 2000) to transcribe the excerpts (i.e., two per day for 3 days, resulting in six 5-min transcripts per family). Two trained research assistants proofread and corrected all transcripts. Across transcripts, and after excluding babbling, we computed the D scores for the study child and all adult speakers using the VOCD command in Computerized Language Analysis (CLAN; MacWhinney, 2000).

Child cognitive ability. The PARCA assesses cognitive skills in early childhood. For the current study, items were selected from the PARCA versions for children aged 2 and 3 years (Oliver et al., 2002; Saudino et al., 1998). First, parents reported within the study's online survey if their child could perform a set of 28 activities, for example "can your child stack seven small blocks on top of each other by him or herself?" Responses were recorded as *yes*, *no*, and *I don't know*. PARCA parent report ratings were then summed. Second, parents completed a PARCA testing booklet together with their child at home. The booklet consisted of three tests, including nine drawing tasks, seven copying tasks and 10 matching tasks. PARCA responses were independently scored by two research assistants, in line with the test's scoring guidelines (Oliver et al., 2002; Saudino et al., 1998), with an initial agreement rate of 92.9% and 100% after resolving differences through discussion with reference to the coding instructions. Composite scores for the three sections of the PARCA booklet tests (i.e., drawing, copying and matching), which correlated .33, .42, and .51, were calculated, z transformed and summed.

The parent-report and parent-administered sections of the PARCA have been shown to correspond to scores from the BSID-II Mental Development Index in a sample of 107 2-year-olds (MDI; Bayley, 1993; $r = .39$, $p < .001$ and $r = .27$, $p < .01$, respectively; Saudino et al., 1998). In addition, the total PARCA was validated against the nonverbal component of the McCarthy Scales of Children's Abilities in a sample of 85 3-year-olds (McCarthy, 1972; $r = .54$, $p < .001$; Oliver et al., 2002). A revised version (PARCA-R) is now part of the United Kingdom's National Institute for Clinical Excellence's (2017) guidelines for developmental assessment, which substantiates the validity of parent-administered tests for the assessment of children's cognitive ability (Blaggan et al., 2014; Martin et al., 2013).

Child behaviour. After reviewing two seminal assessments for childhood behaviour problems—the Child Behaviour Checklist for Ages 1.5 to 5 years (CBCL; Achenbach & Rescorla, 2000), and the Rutter Scale (Rutter, Tizard, & Whitmore, 1970)—we identified 10 adjectives that described internalising (anxious, worried, tearful, depressed), externalising (irritable, disobedient, aggressive), and hyperactive (restless, impatient, distracted) behaviours. Child behavioural analysis was conducted on the same 5-min excerpts that were previously selected for the lexical diversity analysis (i.e., six excerpts per child based on the highest number of conversational turns in LENA during the mornings and evenings). As the majority of children in our study had siblings, we included excerpts with multiple children, because this better reflected the natural home environment. Two research assistants were trained to rate the children's behaviours on the audio-recordings, not the written transcripts, using a scale from 1 to 10. A rating of 5 indicated "normal behaviour," while deviations from 5 indicated atypical behaviour. A rating of 10 indicated the behaviour was extremely excessive, while 0 indicated the behaviour was notably absent (see supplemental materials, and Tables 2.8 and 2.9).

Parenting. We selected 8 items that referred to audible behaviours from the Parenting Styles and Dimensions Questionnaire (PSDQ; Robinson, Mandleco, Olsen, & Hart, 1995). In addition, 2 items from the "opportunities for variety in daily stimulation" subscale of The Home Observation for Measurement of the Environment (HOME, Caldwell & Bradley, 1984) were added. Trained research assistants rated how often the behaviour occurred on the 5-min audio-excerpts on a 5-point scale, ranging from 1 = *never*, 2 = *once in a while*, 3 = *about half the time*, 4 = *very often*, to 5 = *always* (see supplemental materials and Tables 2.1 and 2.2).

Socioeconomic status. Socioeconomic status was indexed by three markers, which were *z* transformed and summed, with the emerging index score being adjusted for the number of markers available per family (e.g., information from both parents). (1) Educational attainment: Each parent stated their highest educational qualification, ranging from school leaving certificate, national vocational qualification, undergraduate degree to postgraduate degree. (2) MacArthur Scale of Subjective Social Status (Adler, Epel, Castellazzo, & Ickovics, 2000): Parents were shown a drawing of a ladder with 10 rungs and the following instructions: “Think of this ladder as representing where people stand in our society. At the top of the ladder are the people who are the best off, those who have the most money, most education, and best jobs. At the bottom are the people who are the worst off, those who have the least money, least education, and worst jobs or no job.” Parents were then asked to indicate the rung that best represented their own SES, with 1 referring to low and 10 to high SES. The MacArthur scale has previously been validated against a composite of income, education and occupation (r = .40, p < .01, N = 157; Adler et al., 2000), and a composite of education and occupation (r = .53, p < .01, N = 177; John-Henderson, Jacobs, Mendoza-Denton, & Francis, 2013). (3) Overcrowding index: Parents reported the number of adults and children currently living in their household. Furthermore, they were asked “how many rooms, not counting bathroom, kitchen or box room, are in your home?” Each family’s overcrowding score was calculated by dividing the number of rooms in the home by the number of people in the household such that a higher score represents less overcrowding.

Validation of Measures Based on Naturalistic Observations

Adult word counts. In total, 622 transcribed excerpts from 107 families were available (out of the maximum possible of 642), including 92 families with 6 excerpt transcripts and 15 families with 4 or 5 excerpt transcripts. To validate the accuracy of LENA’s adult word count estimates, we randomly selected 64 excerpts (roughly 10%) from the 622 available human-transcribed excerpts for analysis in CLAN with the FREQ command, which gives the number of words for each speaker (MacWhinney, 2000). We compared the total adult word count estimate from the CLAN output to the estimate produced by LENA for the same 5-min excerpt. Adult word counts produced by LENA ranged from 35 to 690 with a mean of 245 (*SD* 128), while the adult word counts from CLAN based on traditional transcription ranged from 41 to 603 with a mean of 275 (*SD* 120). Differences in word counts were largely attributable to (a) the degree of distance of the speaker to the microphone and (b) mispronunciation. If the distance between speaker and DLP is greater than six feet, LENA fails to accurately record the adult spoken words (Xu, Yapanel, & Gray, 2009). However, trained typists, who can increase the volume on a recording during the process of transcription, are able to document even extremely distant and faint language. Regarding mispronunciation, LENA is more lenient in accepting “phones” as correct elements of speech, while trained typists coded mispronunciations and nonwords, which are not included in the adult word count. The correlation between LENA and CLAN based adult word counts across 64 recordings of 5 minutes each was .79 ($p < .001$), which increased to .83 ($p < .001$) after adjusting for recording distance.

Lexical diversity. We derived estimates of lexical diversity for each child in the study, as well as for the adult speakers in the child's environment. Because previous research showed that the complexity of adult language changes as a function of the number of children present (Huttenlocher, Vasilyeva, Waterfall, Vevea, & Hedges, 2007), we tested the consistency of D scores in a subsample of 116 transcripts from 58 families for whom at least two excerpt transcripts of the same parent and child were available (19% of all transcripts; 54% of all families). For families with more than two eligible excerpt transcripts, two were randomly selected. For families where both parents had two eligible excerpt transcripts with their child, the two with the mother were chosen, because mothers typically spend more time with their children compared with fathers (Craig & Powell, 2012). Adult lexical diversity was adjusted for the number of excerpts available in our analysis.

Children's D scores from the two excerpts correlated at .58, ($p < .001$), while the parents' D scores correlated only at .23 ($p = .09$). We also computed D scores for children and their language environment based on the two combined excerpt transcripts. Parents' D scores intraclass correlations (ICCs) were similar between the combined transcript and transcript 1 (ICC = 0.39, $p < .001$), and the combined transcript and transcript 2 (ICC = 0.45, p .001). Children's D scores between the combined transcript with transcript 1, and transcript 2 were consistent (ICC = 0.72, $p < .001$ and ICC = 0.65, $p < .001$, respectively). These analyses suggest that children's lexical diversity is fairly stable across excerpts but that of their language environment is not.

To estimate the lexical diversity of adult and child speech, we combined data from all available transcripts per family, and a total D score for all adults combined per family was computed along with a total D score for each child.

Parenting behaviours. Recordings which contained only one parent and no other adult speakers (319 recordings from 104 families) were selected for parenting analysis, parenting behaviours were adjusted for the number of excerpts available for each parent. Estimates of parenting behaviours were based on ratings from two trained research assistants. For the rating process, recordings were randomised to avoid raters listening to excerpts from the same family in succession. To assess the validity of our behaviour coding method, we first tested the interrater agreement for parenting ratings in a subsample of 51 families for whom there were two (or more) recordings with just the mother and child (Table

2.1). For those families with more than two recordings, two recordings were randomly selected. Agreement between raters was high, with an average of 73%. Therefore, we tested the interrater agreement for parenting ratings across all available recordings (Table 2.2), which again resulted in an average agreement between raters of 73%. Parenting ratings from the two raters' scores were then averaged.

We then tested the within-family consistency of parenting (i.e., correlation between mothers' and fathers' parenting within the same family). Absolute differences across recordings were small (see supplemental materials, Table 2.4) and therefore we computed overall parenting behaviour scores across both parents per family (Table 2.5). These summary scores were subjected to factor analysis, with varimax rotation using the R-package "nFactors" (Raiche, 2010), after excluding physical punishment (no variance) and spoils (ambiguous item). Analyses suggested retaining two factors, with the first accounting for 27% and the second for 18% of the variance. One factor represented "positive parenting" (e.g., responsive) and the other "critical parenting" (e.g., threatening; Table 2.7). Composite scores for positive and critical parenting behaviours were computed by summing the mean total scores for each item assigned to their respective parenting behaviour. See the supplemental materials for more details.

Child behaviours. Child behaviour analysis was performed on the full sample of 622 recordings from 107 families. As with the parenting behaviours, two trained research assistants rated child behaviours from randomised recordings. To assess the validity of our child behaviour coding method, we tested the interrater agreement for child behaviours in a subsample of 51 recordings (Table 2.8). After establishing good interrater agreement, on average 80%, in the subsample, we tested the interrater agreement of child behaviours across all available recordings (Table 2.9). Given the high level of agreement between the two raters, on average 79%, their child behaviour codes were averaged for each recording. Total scores for each child behaviour were then created by calculating mean child behaviour scores across the available recordings for each family (Table 2.10).

For childhood behaviour ratings, we subjected the respective summary scores (i.e., across raters and recordings) to factor analysis, in the same way as described previously for parenting behaviours. Parallel analysis suggested extracting two factors, with the first accounting for 22% and the second for 16% of the variance. One factor represented "internalising behaviour problems" (e.g., anxious, worried, tearful) and the other represented "externalising behaviour problems" (i.e., impatient, distracted, irritable; Table 2.13). Accordingly, an internalising and externalising behaviour problem score was computed for each child (Table 1.2). Further details of the consistency and structure of child behaviour are reported in the supplemental materials, along with scatter-plots of the correlations between parenting and child behaviour dimensions (Figure 4).

Statistical Analysis

First, we sought to determine the total number of words that children heard from adults over the 3 recording days. Recording durations were regressed onto LENA adult word counts; unstandardised regression residuals were saved to represent adult word counts here and in all subsequent analyses. Second, we tested the stability of adult word count estimates within families across hours and days with ICCs using the R package ICC (Wolak, Fairbairn, & Paulsen, 2012). A high ICC suggests that adult word count estimates are consistent within families across time. Third, we fitted linear regression models to test associations between markers of children's early life experience, including (a) adult word counts, (b) adult lexical diversity, (c) parenting behaviours, and (d) family background (i.e., SES and birth order), and children's outcomes, including (a) cognitive ability, as indexed by PARCA booklet scores and parent report ratings, (b) child lexical diversity, and (c) child internalising and externalising behaviours. Models were fitted separately for each outcome (i.e., five models), which were adjusted for child age and gender, saving standardised regression residuals.

2.4 Results

Descriptive statistics for all study variables are displayed in Table 1.2, and their correlations are displayed in Table 2.15.

Adult Word Counts

The durations of all 321 recordings (i.e., 3 days of recordings from 107 families) ranged from 5.81 hr to 18.08 hr with a mean of 15.06 hr (*SD* = 1.87). The recordings continuously documented all aspects of life in the families, including times when the study child slept. After adjusting for recording duration, average daily adult word count estimates ranged from 5,471.67 to 33,476.64 across families with a mean of 17,842.50 words (*SD* = 5733.98; Table 1.2).

Consistency of adult spoken words across days. Across families' three days of recordings, adult word count estimates correlated .42, .46 and .56 within families. The ICC for adult word counts within families across days was .47, suggesting that about half of the variance in adult word counts occurred within, and half between, the families (Figure 2). The absolute difference of adult word count estimates within families across days (similar to *SD*) ranged from 350 to 14,433 words with a mean of 3,477 (*SD* = 2,443). Thus, the number of adult spoken words that children heard differed on average by almost 3,500 words within their families across days. After excluding families whose adult word count estimates differed by more than 8,000 words across 3 days (*N* = 7), the ICC coefficient increased to .58, with the difference of adult word count estimates averaging 3,060 (*SD* = 1,714, range 361 to 7,847 words). Thus, excluding extremely variable families only marginally increased the consistency of language experiences within families.

Consistency of adult spoken words across hours. We selected all full hours from the available recordings (4,609 out of 5,321 hr) that registered at least one adult word (3,740 out of 4,609 hr) to exclude recording hours during which the child was most likely asleep. Adult word count estimates ranged from 1 to 7,300 words (*M* = 1,458, *SD* = 1145) across full hours of recordings and families. The corresponding ICC was .14, suggesting that adult word counts vary greatly across hours of the day and that variance in adult word counts occurred mainly within rather than between families (Figure 2).

Associations between the Home Environment and Children's Outcomes

The regression results for children's verbal and cognitive outcomes are shown in Table 1.3; the results for children's behavioural outcomes are in Table 1.4. Differences in the PARCA booklet scores were significantly predicted by adult word counts (*B* = .16, 95% CI [.08, .53], $p < .001$), and child lexical diversity was predicted by adult lexical diversity (*B* = .42, 95% CI [.24, .60], $p < .001$), birth order (*B* = .41, 95% CI [.71, .10], $p < .01$) and SES (*B* = .44, 95% CI [.12, .75], $p < .01$; Table 1.3). By comparison, the PARCA parent report ratings were not significantly associated with any of the predictor variables. Child internalising behaviour was predicted by critical parenting (*B* = .30, 95% CI [.10, .50], $p < .01$), although the model itself did not reach significance ($p = .10$), and child externalising behaviour was predicted by positive parenting (*B* = .25, 95% CI [.45, .04], $p < .05$). We note that the behavioural measures in our study showed only modest variance, which may have weakened the explanatory power of our regression models, because the children in our sample were overall well-adjusted. Overall, the quantity and lexical diversity of adult speech was associated with children's cognitive and language ability, while parenting was related to children's behavioural outcomes.

Table 1.2
Descriptive Statistics of all Study Variables

	Mean	*SD*	Minimum	Maximum	Cronbach's alpha
Adult word counts[a]	17,842.50	5,733.98	5,471.67	33,476.64	-
Adult lexical diversity[b]	46.92	13.89	-8.01	75.01	-
Child lexical diversity[c]	67.61	18.91	29.83	118.96	-
PARCA – standardised[cd]	0.13	0.58	-1.22	1.63	.68
Parent report[c]	20.03	2.70	10.96	25.52	.72
Positive parenting[b]	2.68	0.54	0.96	4.06	.71
Critical parenting[b]	1.00	0.04	0.97	1.32	.53
SES index	-0.03	0.57	-1.69	0.95	-
Internalising behaviour[c]	4.97	0.11	4.71	5.25	.70
Externalising behaviour[c]	5.08	0.08	4.87	5.24	.63

Note. Descriptives are based on complete data N = 104 except where indicated otherwise. Variables corrected for [a] recording duration, [b] number of available recordings, [c] age and gender. [d] N = 101. Parenting was rated on a scale from 1 to 5, and child behaviour on a scale from 1 to 10.

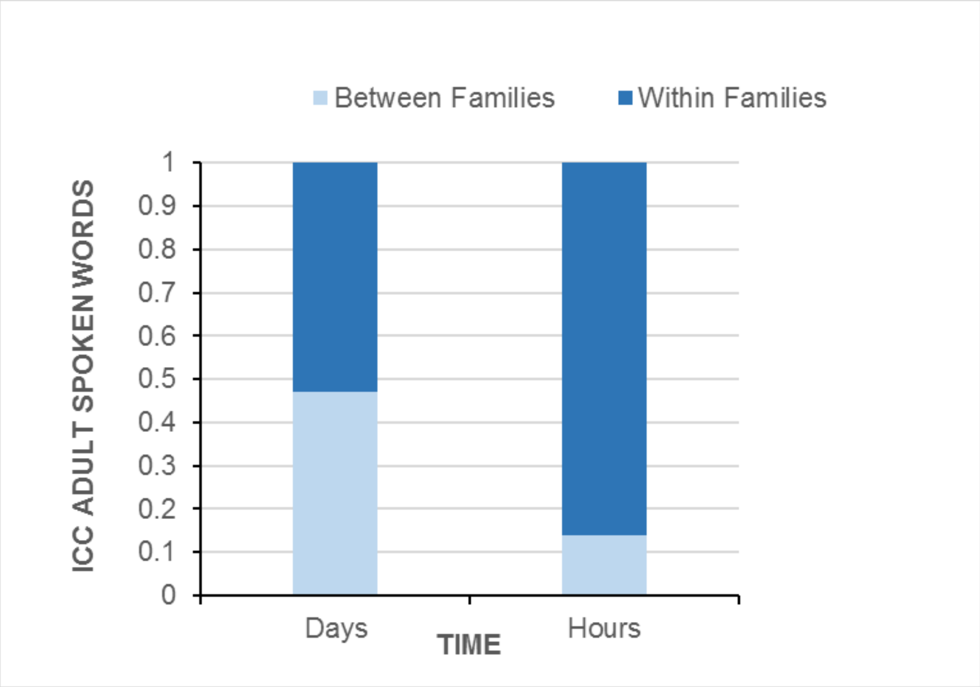

Figure 2. Intra-class correlations (ICC) of home language input (i.e., quantity of adult spoken words) across hours and days. A low ICC suggests that home language input differs more within than between families.

Table 1.3

Regression Model Results for Predicting Children's Cognitive and Language Ability

	PARCA[cd]					Parent report[c]					Child lexical diversity[c]				
	B	*SE B*	β	95% CI		*B*	*SE B*	β	95% CI		*B*	*SE B*	β	95% CI	
Adult word counts[a]	**.16**	**.04**	**.39**	**.08**	**.53**	.01	.05	.02	-.08	.10	-.01	.04	-.02	-.09	.07
Adult lexical diversity[b]	.10	.09	.10	-.09	.25	-.07	.10	-.07	-.28	.13	**.42**	**.09**	**.42**	**.24**	**.60**
Positive parenting[b]	.12	.10	.12	-.08	.31	-.02	.11	-.02	-.23	.20	.10	.09	.10	-.08	.29
Critical parenting[b]	.14	.09	.14	-.05	.32	.06	.10	.06	-.15	.26	-.07	.09	-.07	-.25	.11
Birth order	-.01	.16	-.00	-.33	.31	-.34	.18	-.21	-.69	.01	**-.41**	**.15**	**-.25**	**-.71**	**-.10**
SES index	.13	.18	.07	-.22	.48	.32	.18	.18	-.04	.68	**.44**	**.16**	**.25**	**.12**	**.75**
R^2	.22					.08					.28				
F	4.43					1.34					6.31				
p	< .001					.25					< .001				

Note. Variables corrected for [a] recording duration, [b] number of available recordings, [c] age and gender, [d] N = 101. Predictors significant at $p < .01$ are shown in bold.

Table 1.4

Regression Model Results for Predicting Children's Behavioural Outcomes

	Internalising behaviour[c]					Externalising behaviour[c]				
	B	*SE B*	β	95% CI		*B*	*SE B*	β	95% CI	
Adult word counts[a]	-.04	.04	-.09	-.13	.05	.03	.04	.06	-.06	.11
Adult lexical diversity[b]	-.12	.10	-.12	-.32	.08	.14	.10	.14	-.06	.33
Positive parenting[b]	.01	.10	.01	-.20	.22	**-.25**	**.10**	**-.25**	**-.45**	**-.04**
Critical parenting[b]	**.30**	**.10**	**.30**	**.10**	**.50**	.18	.10	.18	-.02	.37
Birth order	.04	.17	.02	-.30	.38	.07	.17	.04	-.27	.40
SES index	-.00	.18	.00	-.35	.35	-.05	.17	-.03	-.39	.30
R^2	.10					.14				
F	1.85					2.73				
p	.10					.02				

Note. Variables corrected for [a] recording duration, [b] number of available recordings, [c] age and gender, [d] $N = 101$. Predictors significant at $p < .01$ are shown in bold.

2.5 Discussion

We used naturalistic observations in the family home to investigate associations between early life experiences of language and parenting, and children's cognitive, language and behavioural outcomes. We found that early life experiences of adult speech, including the quantity and quality of language that children heard over the course of three days, varied as much within as between families. This finding extends previous studies, which assumed children's language experiences to be very stable and thus, to vary mostly between families but not within. However, in line with previous research, we also found that the overall quantity of adult speech that children were exposed to was positively associated with their cognitive ability (Caskey et al., 2014; Hart & Risley, 1995). In addition, we showed that a marker of the quality of adult speech, adults' lexical diversity, was associated with children's own lexical diversity. However, the quantity of adult speech was not related to children's lexical diversity, and the lexical diversity of adult speech was also not related to children's cognitive ability. Finally, we found that positive parenting—parenting behaviours that are responsive and encourage children's self-expression and novelty seeking—was associated with lower levels of child externalising behaviours but not with cognitive or language abilities. Likewise, critical parenting was associated with children's internalising behaviours, such as depressive, anxious and socially withdrawn tendencies, but not with their cognitive or language outcomes. We discuss our results in the context of existing literature, noting strengths, limitations and future directions.

Home Language Input

Several previous studies that used LENA to collect naturalistic observations of American families have reported that children heard on average between 12,800 and 13,142 adult spoken words over the course of a 12-hr day (Christakis et al., 2009; Greenwood et al., 2011; Zimmerman et al., 2009). Our estimate of the average daily word count of 17,843 words for a 15-hr day is only slightly higher and this discrepancy is likely to result from samples' differences in educational attainment. In our study, 86% of mothers held university degrees compared with 26% reported in both the studies described above (Christakis et al., 2009; Zimmerman et al., 2009). Similarly, fathers were more educated in our sample with 78% possessing university degrees compared with 23% and 24% reported by Christakis et al. (2009) and Zimmerman et al. (2009), respectively. We note that our estimates were considerably lower than those noted by Hart and

Risley's (1995), who estimated daily adult word counts to be 30,100 in professional families and 17,500 words in working-class families. Hart and Risley's (1995) overestimations are likely to result from extrapolating data from hour-long recordings, under the assumption that children's exposure to adult speech is stable across hours in the day.

Our findings suggest that adult speech varies considerably across hours and days. Previous studies have shown that the quantity of adult speech peaks during the morning and early evening but is reduced around midday (Greenwood et al., 2011), and we replicate this finding in Figure 3. It has been proposed that certain daily activities yield more adult speech than others, for example book reading, which often occurs at bedtime, produces more adult speech per unit time than mealtimes or toy-play activities (Weizman & Snow, 2001). Across the 3 recording days, we observed that almost as much of the variance in the amount of adult speech occurred within as between families. Our results are comparable to Gilkerson et al.'s (2017) reports of a correlation of .66 between adult word counts on consecutive days, however this correlation reduced to around .40 when the time span between observations increased to between 4 and 16 weeks. Taken together, these findings suggest that there is a vast amount of within family variance in adult speech.

Although our sample's restriction of range in SES may have emphasised the within-family differences, the observation of substantial variance in adult speech within families appears not to be sample specific but generally underreported in the literature (Greenwood et al., 2011). Nevertheless, it is typical to observe large within SES group variation in adult speech, even within low SES samples (e.g., Weisleder & Fernald, 2013).

We also observed that lexical diversity varied considerably among adults across recording excerpts, so that the majority of variance occurred within rather than between families. By contrast, children's lexical diversity was fairly stable across assessments. Future research must explore if our findings are specific to times of high conversational turns.

Finding large within-family differences in adult speech suggests that between-family differences may have less dramatic effects on the development of children's language abilities than previously thought. On a particular day, two families may produce similar quantities of adult speech, but on the next day, they may differ vastly in speech. Our findings emphasise that early life experiences, especially with regard to language, are dynamic processes that change and evolve over time, rather than static environmental determinants.

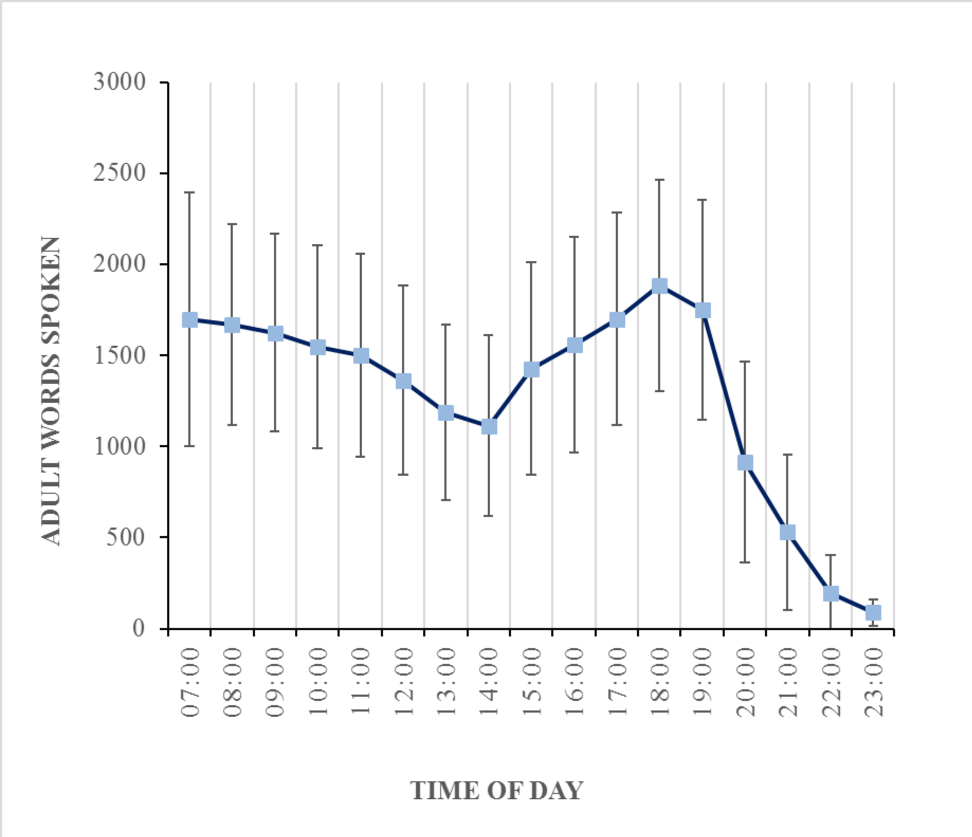

Figure 3. Home language input (i.e., quantity of adult spoken words) over the duration of a day, averaged across families. Error bars reflect standard deviation.

Home Language Input and Children's Cognitive and Language Ability

Confirming our hypothesis, we found that the quantity of adult spoken words that children heard was positively associated with their cognitive ability as indexed by the PARCA booklet. However, the mechanisms that underlie this association remain speculative. It is possible that a greater exposure to language provides greater learning opportunities for children, or that children's cognitive ability may actively influence adults' spoken language (Song, Spier, & Tamis-LeMonda, 2014). As an alternative, it may be that a third factor explains why the quantity of adult speech and children's cognitive ability are associated, for example shared genetic predispositions (i.e., gene–environment correlations; Ayorech, Krapohl, Plomin, & von Stumm, 2017).

We found no meaningful association between adult word counts and parent reports of their children's cognitive ability. One explanation might be that parent reports were completed at study enrolment whereas the PARCA booklet was administered later on in the study, when the recordings were also done. The difference in the time of assessment may have affected the validity of the parent reports. As an alternative, parents may be less accurate in assessing their child's abilities through a rating scale compared with when the child actually demonstrates cognitive skills in a test. In any case, the correlation between parent reports and children's booklet test scores in the current study was comparable to previous reports (e.g., Saudino et al., 1998).

In the current study, we differentiated the quantity and quality of adult speech and observed specific associations for both markers with children's lexical diversity, in line with previous research (Hart & Risley, 1995; Hoff, 2003; Huttenlocher et al., 2010; Pan et al., 2005). Specifically, the lexical diversity of adult speech but not the quantity was related to children's lexical diversity, so that children who experienced more lexical diversity in their home environment also produced language of greater lexical diversity themselves. However, our estimate that adult lexical diversity predicted 17.6% of the variance in children's language ability is notably higher than the 9.5% previously reported (Rowe, 2008). An obvious explanation for this finding is that estimates of adult and child lexical diversity were not independent in the current study but extracted from the same conversational interactions. By contrast, the number of words that a child heard was estimated over the course of the day and not based on one interaction. An alternative, substantive explanation is that estimates of lexical diversity reflect child-directed speech that facilitates adequate parental scaffolding, which enables children to learn and practice word meanings (Hirsh-Pasek et al., 2015). This interpretation is supported by the observation of significant effects of SES and birth order on children's lexical diversity, which were not evident for any other outcome variable suggesting that early life circumstances are mirrored more closely by children's lexical diversity than by their cognitive ability. An important avenue for future research is to explore the relationship between the quantity of adult speech and the amount of child-directed speech as they occur in the family home, and how they respectively relate to children's cognitive and language outcomes.

Parenting and Child Behaviours

We found here that using audio-recordings was a feasible method for assessing real-life parenting and child behaviours, free from the limitations of observer reactivity (Gardner, 2000). Finding concurrent associations between parenting and child behaviours in the theoretically expected direction confirms the validity of our assessment method. More explicitly, we found that positive parenting was inversely associated with children's externalising behaviour, in that parents, who were more responsive to their child's needs and encouraged exploration and self-expression, had children that showed fewer restless, attention-deficit, irritable, or disobedient behaviours. This finding is in line with studies using traditional parent-reports methods (Barnes et al., 2010; Stein et al., 2013). There was also an association between critical parenting and children's internalising behaviours in our study, with children of parents who engaged more often in critical parenting being more often anxious, worried, and tearful. Because the overall regression model did not reach significance, this result is somewhat untenable.

Strengths and Limitations

Our study has several notable strengths: We are, to our knowledge, the first to report typical daily adult word counts in a comparatively large British sample obtained through naturalistic daylong audio-recordings. In addition, these recordings were of substantial durations to capture real-life interactions in the family home. Thus, the current study is the largest naturalistic observation study of early life home environments to date.

Nevertheless, our study also suffers limitations. First, our sample had a restricted SES range and therefore, it was not representative of the general population. However, the associations between adult speech and child outcomes should exist irrespective of SES, although we encourage future research to test more economically diverse families. Second, our cross-sectional design precludes conclusions of causality. Longitudinal studies are needed to clarify whether, for example, more intelligent children evoke more words from adults in their environment or vice versa. Third, our study children ranged considerably in age capturing a wide window of development, which reduces the validity of age-specific inferences. Fourth, we relied on 30 min of audio-recordings per family to analyse their lexical diversity and behaviours, which may be too short to derive valid measures, although our reliability analyses suggest otherwise. Finally, we used interrater agreements to indicate the validity of our behaviour coding, but future research must test the extent to which data on parenting from audio-recording matches that from self- and observer-report questionnaires.

2.6 Conclusion

Using unobtrusive daylong naturalistic audio-recordings, we show that the quantity of adult speech that children are exposed to varies greatly across days and within families. We also showed that early life language and parenting experiences are differentially associated with children's cognitive, language, and behavioural outcomes. We suspect that distinct developmental processes underlie these associations, which can only be understood if early life experiences are conceptualised as the dynamic, changing phenomena that they are, rather than as static entities. Such approaches will help elucidate the interplay between environmental experience and children's differences in development.

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3 Paper 1: Supplemental Material

3.1 LENA Pro Software

LENA Pro software uses algorithms to provide estimates of adult word counts, based on automatic speech recognition (ASR) software (Richards, Gilkerson, Paul, & Xu, 2008). The ASR software has three main stages: (1) feature extraction, (2) phone decoding and (3) a language model. First, language on the audio files is segmented into eight source categories (e.g., male; female; child; electronic media; Xu, Yapanel & Gray, 2009). Next, the "phones" that refer to distinct speech sounds are counted by the phone decoder. Phones are acoustically similar to phonemes but are more broadly defined sound categories, and can therefore be utilised to quantify children's emerging speech. Lastly, the language model converts the phone sequence into words, phrases and sentences.

In previous research, LENA adult word count estimates correlated .92 ($p < .01$) with adult word counts derived via traditional human transcription across 70 hours of recordings (Xu et al., 2009). Furthermore, adult word counts derived from LENA and human transcription differed by 0.4%, based on one complete 12-hour recording of a quiet day (i.e., mainly indoors; few speakers).

3.2 Lexical Diversity: D Scores

D scores are based on the probability of new vocabulary being introduced into progressively longer samples of speech (Malvern, Richards, Chipere, & Durán, 2004). McKee, Malvern, and Richards (2000) describe how D scores are computed: Within a speech sample, as the token size (i.e., the number of words) increases, the ratio between the tokens and types (i.e., different words used) decreases. As the type token ratio (TTR) falls in a predictable manner in all speech samples, a theoretical mathematical model is used to model the lexical diversity of speakers. To obtain D scores for each speaker, the VOCD command in CLAN first plots a TTR x token curve for each token size from 100 trials of randomly chosen words without replacement throughout the speech sample. The program then uses a curve-fitting procedure that finds the best fit between the theoretical model and the empirical data by adjusting values for D. The resulting D score is therefore an estimation of the lexical diversity of the speaker.

D scores have several advantages over other measures of lexical diversity such as the type token ratio. Notably, D scores are not a function of the number of words in a sample and therefore are comparable across speakers and studies

(McKee et al., 2000). This feature ensures all data within a sample is used, by contrast, researchers using type token ratios often truncate their data to a particular token size to allow valid comparisons across their participants (McKee et al., 2000).

3.3 Parenting Behaviour

Parenting Items

Raters coded how often a parenting behaviour occurred on the audio-recordings, 1 = *never*, 2 = *once in a while*, 3 = *about half the time*, 4 = *very often*, 5 = *always*. The 10 parenting behaviours measured were 1) shout when their child misbehaves, 2) use physical punishment as a way of disciplining their child, 3) give comfort, and understand when their child is upset, 4) respond to their child's feelings and needs, 5) reason with their child about appropriate behaviour, 6) spoils their child, 7) threaten their child with punishment more often than actually giving it, 8) criticise their child, 9) encourage their child to express him/ herself in different ways, and 10) encourage their child to try and learn new things.

Consistency of Parenting Coding Between Raters

The absolute difference between raters' codes calculated in a subsample of 51 families, for whom there were at least two recordings containing just the mother and child but no other speakers (Table 2.1) was comparable to the same analysis undertaken using the full sample (Table 2.2). Thus, the consistency of coding between raters was similar regardless of whether the recordings contained only the two focal speakers (i.e., parent and child) or several speakers.

Two trained raters independently coded parenting behaviours in each of the available recordings for 104 families. Their absolute difference in ratings are shown in Table 2.2. Agreement between raters was high, with an average of 73%. Items with notably lower agreement were responsive (33.54%), reasons (57.37%), expression (17.87%) and novelty (57.68%). The mean absolute difference between raters was typically below 1, though it was slightly higher for reasons, expression and novelty. Because scores were so consistent across raters, intra-class correlations could not be computed (i.e., lack of variance). For each recording, the two raters' codes for each parenting behaviour were averaged.

Consistency of Parenting

Intra-class correlations were calculated to assess the consistency of parenting within families across the two recordings (Table 2.3). These ICCS were very low suggesting that there is within family variation in parenting. Shouting and expression parenting behaviours showed comparably higher consistency with ICCs of .43 and .38 respectively.

Additionally, mothers' and fathers' parenting behaviour was compared in a subsample of 39 families for whom we had recordings of both parents. Table 2.4 displays descriptive statistics and correlations.

Total scores were then created for each family by calculating mean parenting behaviour scores across their available recordings; Table 2.5 displays descriptive statistics for total parenting behaviours. Note that there was no variance in physical punishment in our sample (i.e., physical punishment did not occur on any of the recordings). Correlations between parenting behaviours are displayed in Table 2.6; in line with expectations positive associations were evident between comfort and reasons (r = .24), threatens and criticises (r = .44), expression and novelty (r = .58), and between shouts and threatens (r = .20).

Table 2.1

Consistency of Parenting Codes Between Raters in Subsample

Parenting behaviour	Identical codes (%)	Absolute difference of 1 (%)	Absolute difference of 2 (%)	Absolute difference of 3+ (%)	Mean absolute difference
Shout	97.06%	0.98%	1.96%	-	0.05
Physical	100%	-	-	-	0.00
Comforts	78.43%	6.86%	1.96%	12.74%	0.53
Responsive	37.25%	52.94%	8.82%	0.98%	0.75
Reasons	56.86%	6.86%	14.71%	21.57%	1.09
Spoils	95.10%	4.90%	-	-	0.05
Threatens	99.01%	0.98%	-	-	0.03
Criticises	93.14%	6.86%	-	-	0.07
Expression	15.68%	17.65%	27.45%	39.22%	1.99
Novelty	60.78%	8.82%	9.80%	20.59%	0.95

Note. Mother-child only recordings (*n* = 51 families, 102 recordings).

Table 2.2

Consistency of Parenting Codes Between Raters in Full Sample

Parenting	Identical codes (%)	Absolute difference of 1 (%)	Absolute difference of 2 (%)	Absolute difference of 3+ (%)	Mean absolute difference
Shout	97.18%	1.88%	0.94%	-	0.04
Physical	100%	-	-	-	0.00
Comforts	79.31%	5.64%	2.85%	12.23%	0.52
Responsive	33.54%	52.04%	11.91%	2.51%	0.84
Reasons	57.37%	7.52%	9.09%	26.02%	1.13
Spoils	94.67%	4.08%	1.25%	-	0.07
Threatens	97.49%	1.88%	0.31%	0.31%	0.03
Criticises	96.55%	3.48%	-	-	0.03
Expression	17.87%	18.8%	22.88%	40.44%	1.95
Novelty	57.68%	10.34%	9.72%	22.26%	1.04

Note. *N* = 104 families with 319 recordings. 6 families had 6 recordings; 13 families had 5 recordings; 20 families had 4 recordings; 19 families had 3 recordings; 35 families had 2 recordings; 11 families had 1 recording.

Table 2.3

Intra-Class Correlations for Parenting in Subsample

Parenting behaviour	ICC
Shout	.43
Physical	-
Comforts	.13
Responsive	.13
Reasons	-.07
Spoils	-.03
Threatens	0
Criticises	-.07
Expression	.38
Novelty	.13

Note. ICC = Intra-class correlations. Subsample includes only mother and child speakers across 2 recordings, $n = 51$.

Table 2.4

Descriptive Statistics and Correlations between Mothers' and Fathers' Parenting Within Families

	Mothers		Fathers		
	mean	*SD*	mean	*SD*	*r*
Shout	1.01	.06	1	0	
Physical	1	0	1	0	
Comfort	1	.67	1.37	.65	.12
Responsive	4.09	.51	3.7	.84	-.08
Reasons	1.63	.07	1.51	.68	.25
Spoils	1.07	.21	1.06	.20	.36*
Threatens	1.01	.06	1	0	
Criticises	1.03	.07	1	0	
Expression	2.85	.62	2.58	.97	.26
Novelty	1.61	.71	1.66	.82	.09

Note. $n = 39$, * $p < .05$

Table 2.5

Descriptive Statistics for Total Parenting Behaviours

Parenting behaviour	Mean	*SD*	Minimum	Maximum
Shout	1.01	.06	1	1.38
Physical	1	0	1	1
Comfort	1.43	.64	1	4
Responsive	3.92	.64	1	4
Reasons	1.7	.63	1	3.5
Spoils	1.03	.10	1	1.75
Threatens	1.02	.09	1	1.75
Criticizes	1.01	.04	1	1.25
Expression	2.81	.71	1	4.67
Novelty	1.67	.63	1	4.33

Note. *N* = 104. Variable anchor ranges 1 = *never* to 5 = *always.*

Table 2.6

Correlations Between Parenting Behaviours

	1	2	3	4	5	6	7	8	9
1. Shout	-								
2. Comfort	.06	-							
3. Responsive	-.03	.17	-						
4. Reasons	.08	.24	.11	-					
5. Spoils	.02	.07	.07	-.08	-				
6. Threatens	.20	-.03	-.03	-.03	-.05	-			
7. Criticises	.30	.07	.07	.09	.00	.44	-		
8. Expression	-.03	.00	.00	.17	-.01	-.11	-.17	-	
9. Novelty	-.14	-.06	-.06	.17	-.06	-.10	-.14	.58	-

Note. *N* = 104.

Parenting Factor Analysis

A factor analysis of the parenting total scores was conducted on all items excluding physical punishment (as there was no variance) and spoils (due to its ambiguous nature, it is not clearly a positive or harsh parenting behaviour). Analyses were conducted using the R package 'nFactors' (Raiche, 2010) which suggested retaining 2 factors (Table 2.7. Factor 1 accounted for 27% of the variance and Factor 2 accounted for 18% of the variance).

Table 2.7
Factor Loadings for Parenting Behaviours

Parenting behaviour	Factor 1	Factor 2
Responsive	.55	
Expression	.99	
Novelty	.57	
Threatens		.50
Criticises		1
Shout		.35

Note. N = 104.

Factor 1 was conceptualised as positive parenting and Factor 2 as critical parenting, a score for each was created for each family. Internal reliability of these scales was acceptable, Cronbach's alphas = .71 and .53 for positive and critical parenting respectively. Table 1.2 displays descriptive statistics for these overall parenting behaviours (variable anchor ranges 1 = *never* to 5 = *always*).

3.4 Child Behaviour

Consistency of Coding between Raters

The absolute difference between raters' codes calculated in a subsample of 51 families, for whom there were at least two recordings containing just mother and child speakers (Table 2.8) was comparable to the same analysis undertaken using the full sample (Table 2.9). Thus, the consistency of coding between raters was similar regardless of whether the recordings contained only the two focal speakers (i.e., parent and child) or several speakers. Two trained raters independently coded child behaviour in each of the available recordings for 107

Table 2.8

Consistency of Child Behaviour Codes Between Raters in Subsample

Child behaviour	Identical codes (%)	Absolute difference of 1 (%)	Absolute difference of 2 (%)	Absolute difference of 3 (%)	Mean absolute difference
Anxious	90.20%	9.80%	-	-	0.10
Worried	89.21%	10.78%	-	-	0.11
Tearful	50.98%	47.06%	1.96%	-	0.51
Depressed	75.49%	24.51%	-	-	0.25
Restless	77.45%	22.55%	-	-	0.23
Impatient	93.14%	6.86%	-	-	0.07
Distracted	72.55%	25.49%	0.98%	0.98%	0.30
Irritable	83.33%	14.71%	1.96%	-	0.19
Disobedient	84.31%	15.69%	-	-	0.16
Aggressive	88.24%	11.76%	-	-	0.12

Note. Mother-child only recordings (n = 51 families, 102 recordings).

Table 2.9

Consistency of Child Behaviour Codes Between Raters in Full Sample

Child behaviour	Identical codes (%)	Absolute difference of 1 (%)	Absolute difference of 2 (%)	Absolute difference of 3 (%)	Mean absolute difference
Anxious	92.28%	7.72%	-	-	0.08
Worried	89.39%	10.61%	-	-	0.11
Tearful	52.73%	46.46%	0.80%	-	0.48
Depressed	68.81%	31.03%	0.16%	-	0.31
Restless	75.24%	24.28%	0.48%	-	0.25
Impatient	83.44%	16.24%	0.32%	-	0.17
Distracted	72.35%	27.17%	0.32%	0.16%	0.28
Irritable	79.58%	19.77%	0.64%	-	0.21
Disobedient	84.08%	15.92%	-	-	0.16
Aggressive	89.23%	10.77%	-	-	0.11

Note. *N* = 107 families, 622 recordings. 92 families had 6 recordings; 10 families had 5 recordings; 5 families had 4 recordings.

families. Their absolute differences in ratings are shown in Table 2.9. Agreement between raters was extremely high, with an average of 79%. The only item with notably lower agreement at 52.73% was tearful. For all child behaviours, when raters differed in their codes, the vast majority of these differed by a score of 1, with only a small proportion differing by a score of 2 or 3 (less than 1% for each behaviour). In all cases, the mean absolute difference score was less than 0.50. Because scores were so consistent across raters, intra-class correlations could not be computed (i.e., lack of variance). Given the high level of agreement between the two raters, their child behaviour codes were averaged for each recording (Table 2.10).

Consistency of Child Behaviour

Total scores for each child behaviour were then created by calculating mean child behaviour scores across the available recordings for each family (Table 2.11). Low standard deviations indicated minimal within-child variance in behaviours. Correlations between child behaviours (Table 2.12) were as expected: anxious, worried, tearful and depressed child behaviours were positively associated (r = .29 to .67). Restless, irritable disobedient and aggressive behaviours were positively associated (r = .20 to .39).

Child Behaviour Factor Analysis

A factor analysis of the child behaviour total scores was conducted using the R package ‘nFactors’ (Raiche, 2010). Parallel analysis suggested extracting two factors; Factor 1, which was conceptualised as ‘internalising behaviour problems’, explained 22% of the variance and Factor 2, which was conceptualised as ‘externalising behaviour problems’, accounted for 16% of the variance (Table 2.13). Accordingly, an internalising and externalising behaviour problem score was computed for each child. Cronbach’s alphas were 0.70 and 0.63 for internalising and externalising behaviour problems, respectively. Table 1.2 displays descriptive statistics for these problem behaviours.

Intra-class correlations were calculated to assess the consistency of children’s behaviour within families across two recordings in which only the mother and child were present (Table 2.14). Overall these ICCs were very low suggesting that there is within-family variation in children’s behaviour; however depressed and irritable child behaviours showed relatively higher consistency (ICC = .41 and .40 respectively) suggesting that these behaviours may show comparably

Table 2.10

Descriptive Statistics for Child Behaviours Averaged Across Two Raters

Child behaviour	Mean	*SD*	Minimum	Maximum	Range
Anxious	5.01	0.14	4.5	6	1.5
Worried	5.04	0.19	4.5	6	1.5
Tearful	4.98	0.46	4.5	6.5	2
Depressed	4.84	0.35	4	6	2
Restless	5.19	0.32	4.5	6.5	2
Impatient	5.16	0.33	4.5	7	2.5
Distracted	5.03	0.30	4	6.5	2.5
Irritable	5.14	0.38	4.5	7	2.5
Disobedient	5.01	0.25	4	6.5	2.5
Aggressive	4.98	0.17	4.5	6	1.5

Note. *N* = 107 Families, 622 Recordings. Variable anchor ranges 0 = *notably absent* to 10 = *extremely excessive* (5 = *normal*).

Table 2.11

Descriptive Statistics for Total Child Behaviour Scores

Child behaviour	Mean	*SD*	Minimum	Maximum	Range
Anxious	5.01	0.06	4.83	5.17	0.34
Worried	5.04	0.09	4.83	5.33	0.50
Tearful	4.99	0.24	4.58	5.67	1.09
Depressed	4.84	0.18	4.42	5.20	0.78
Restless	5.19	0.15	5	5.67	0.67
Impatient	5.16	0.15	5	5.58	0.58
Distracted	5.03	0.12	4.75	5.42	0.67
Irritable	5.14	0.18	4.83	5.67	0.84
Disobedient	5.02	0.11	4.58	5.25	0.67
Aggressive	4.98	0.08	4.67	5.25	0.58

Note. *N* = 107. Variable anchor ranges 0 = *notably absent* to 10 = *extremely excessive* (5 = *normal*).

Table 2.12

Correlations Between Child Behaviours

	1	2	3	4	5	6	7	8	9
1. Anxious	-								
2. Worried	.35	-							
3. Tearful	.42	.48	-						
4. Depressed	.43	.29	.67	-					
5. Restless	-.14	.04	-.04	-.11	-				
6. Impatient	.04	.14	.35	.16	.13	-			
7. Distracted	-.06	.13	.16	.02	.35	.04	-		
8. Irritable	.09	.09	.49	.39	.20	.27	.16	-	
9. Disobedient	-.02	.00	.21	.26	.25	.16	.33	.39	-
10. Aggressive	-.08	-.04	.00	-.04	.38	.22	.24	.30	.21

Note. $N = 107$.

Table 2.13
Factor Loadings for Child Behaviours

Child behaviour	Factor 1	Factor 2
Anxious	0.50	
Worried	0.49	
Tearful	0.93	
Depressed	0.71	
Restless		0.59
Impatient		0.31
Distracted		0.46
Irritable		0.52
Disobedient		0.51
Aggressive		0.58

Note. *N* = 107.

Table 2.14
Intra-Class Correlations for Child Behaviour

Child behaviour	ICC
Anxious	.20
Worried	.06
Tearful	.07
Depressed	.41
Restless	.05
Impatient	.08
Distracted	.10
Irritable	.40
Disobedient	-.05
Aggressive	-.05

Note. ICC = Intra-class correlations. Subsample of only mother and child speakers across 2 recordings (*n* = 51).

less variation within families than behaviours such as tearful and worried (ICC = .07 and .06 respectively).

3.5 Results

Correlations Between Study Variables

Table 2.15 details correlations between all study variables.

Relations between Parenting and Child Behaviour Dimensions

The associations of positive and critical parenting with children's internalising and externalising behaviours are depicted in Figure 4.

Table 2.15

Correlations Between all Study Variables After Listwise Omission

	1	2	3	4	5	6	7	8	9	10
1. Adult word counts[a]	-									
2. Adult lexical diversity[b]	-.03	-								
3. Positive parenting[b]	.33	-.12	-							
4. Critical parenting[b]	-.05	.14	-.21	-						
5. Birth order	-.32	.24	-.20	-.04	-					
6. SES index	.06	.18	.05	-.17	.15	-				
7. PARCA[c]	.40	.11	.21	.09	-.10	.10	-			
8. Parent report[c]	.08	-.07	.02	.02	-.19	.10	.17	-		
9. Child lexical diversity[c]	.11	.38	.12	-.06	-.13	.29	.26	.25	-	
10. Internalising behaviour[bc]	-.09	-.07	-.07	.28	.01	-.08	.05	.03	-.16	-
11. Externalising behaviour[c]	-.04	.19	-.28	.25	.09	-.03	.21	-.16	.01	.26

Note. *N* = 101. Variables corrected for [a] recording duration, [b] number of available recordings, [c] age and gender.

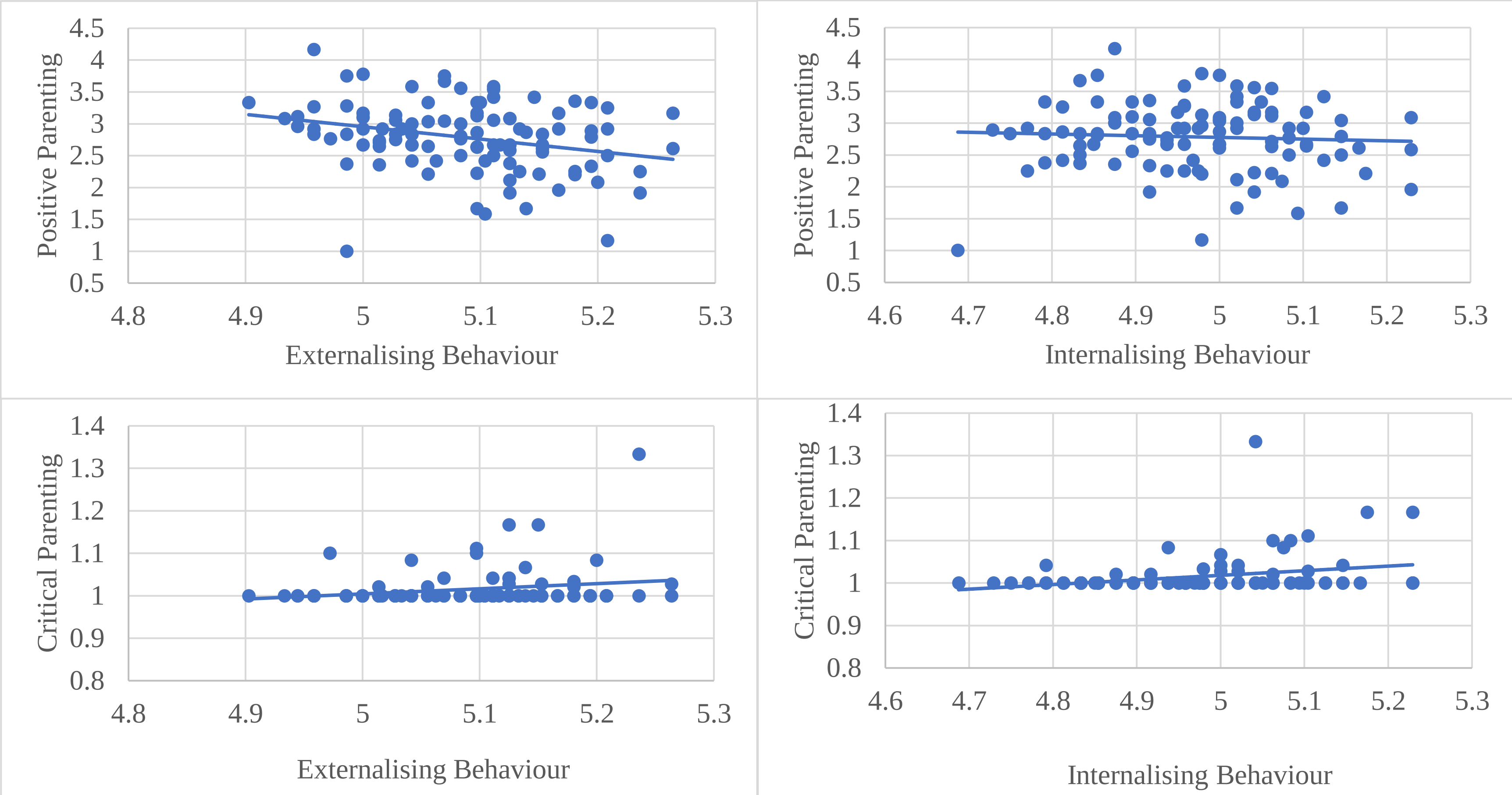

Figure 4. Relations between parenting and child behaviour dimensions.

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4 Paper 2: The Role of Spoken language and Literacy Exposure for Cognitive and Language Outcomes in Children

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4.1 Abstract

Children's language and cognitive development are informed by adult spoken language and parental literacy behaviours, although their relative contributions have not been evaluated. Using digital audio-recorders, we unobtrusively observed the spoken language of 107 children, aged 24 to 48 months (*M* = 32, *SD* = 6.5), and their families over 3 days (*M* = 15.1 hours per day, *SD* = 1.9). Additionally, parents administered a cognitive test to their child and completed measures for their own literacy behaviours. The adult spoken language that children were exposed to accounted for 11% and 12% of the variance in their cognitive and language abilities. Parents' literacy behaviours accounted independently for 4% of the variance in children's cognitive ability but were not associated with their language ability. Parents' literacy behaviours correlated .33 with the quantity of adult spoken language. Our findings suggest that parents' literacy behaviours play a significant role in children's cognitive development.

4.2 Introduction

Children's cognitive and language development is thought to vary as a function of their early life language experiences in the family home. However, it is not clear which type of early life language experience is most pervasive for children's cognitive and language outcomes. Previous studies suggested three important contributors: (a) the quantity (Caskey, Stephens, Tucker, & Vohr, 2014; Hart & Risley, 1995; Zimmerman et al., 2009) and (b) the lexical diversity of adult spoken language that children are exposed to (Huttenlocher, Waterfall, Vasilyeva, Vevea, & Hedges, 2010; Pan, Rowe, Singer, & Snow, 2005; Rowe, 2008), as well as (c) parental literacy behaviours (Baker, 2013; Deckner, Adamson, & Bakeman, 2006). In the current study, we explore for the first time how these three contributors are inter-related, and whether they independently predict children's cognitive and language ability in data from naturalistic home observations.

The exposure to spontaneous adult spoken language in everyday conversations provides opportunities for children to learn words and process spoken language, which trains their ability to apply language fast and accurately (Weisleder & Fernald, 2013). For example, children who hear more diverse adult spoken language, experience more examples of different words, which then increases the lexical diversity of their own spoken language (Hoff, 2003). Furthermore, hearing these different words in a variety of contexts helps children to learn semantic knowledge about the word's meaning (Head Zauche, Thul, Darcy Mahoney, & Stapel-Wax, 2016). In short, the exposure to adult spoken language informs children's own language development and this effect is thought to be enhanced when adults and children engage together in literacy behaviours (Saracho, 2017).

Although no formal definition of literacy behaviours exists, the term is akin to the "home literacy environment" which describes literacy-related interactions, resources, and attitudes that parents provide in the family home (Hamilton, Hayiou-Thomas, & Hulme, 2016). While previous research used a wide range of measures to assess literacy behaviours (Topping, Dekhinet, & Zeedyk, 2013), the vast majority of studies rely on few indicators extracted from parent-reports, such as the number of books in the family home or the frequency of joint book reading (Baker, 2013; Griffin & Morrison, 1997; Puglisi, Hulme, Hamilton, & Snowling, 2017). For the current research, we applied a more comprehensive assessment approach based on three established psychometric scales (Bennett, Weigel, & Martin, 2002; DeBaryshe & Binder, 1994). Thus, we broadly captured formal and informal literacy behaviours that parents typically engage in with their child, for example reciting nursery rhymes, playing language games, storytelling, singing songs and joint book-reading, as well as parental literacy beliefs, which refer to goals, values, and ideas held by parents about literacy (DeBaryshe & Binder, 1994).

Because literacy behaviours involve focused and rich parent-child language interactions, they have been argued to better support children's language and cognitive development than other kinds of verbal exchanges (Baker, 2013). Specifically, previous studies suggest that parents' literacy behaviours expose children to vocabulary that rarely occurs in spontaneous spoken language, because a broader range of rare topics are addressed during literacy-based parent-child interactions than in alternative conversation settings (Mol, Bus, De Jong, & Smeets, 2008). For example, adults engaging in narrative tasks like storytelling use more diverse spoken language than they do in spontaneous everyday conversations (Nippold, Frantz-Kaspar, & Vigeland, 2017), which in turn improves children's vocabulary and comprehension skills (Britto, Brooks-Gunn, & Griffin, 2006; Saracho & Spodek, 2010). Likewise, joint book-reading provides the opportunity for parents to engage in behaviours such as scaffolding dialogue, questioning, relating ideas to personal real-life experiences or offering positive feedback (Saracho & Spodek, 2010), which helps children to develop problem solving skills (Saracho, 2017) and to enhance their understanding of the world (Rodriguez et al., 2009). Although spontaneous adult spoken language and parents' literacy behaviours appear to employ similar language learning mechanisms, their relative contribution to children's cognitive and language development are currently unclear.

Naturalistic Home Observations of Early Life Language Experiences

In early life, children typically spend most of their time in the family home, yet naturalistic home observations of children's exposure to adult spoken language are rare. Studies that do conduct home observations usually involve researchers visiting the homes of families: The physical presence of a researcher may trigger observer reactivity, with any observations not being truly representative of families' natural language and behaviour (Dudley-Marling & Lucas, 2009; Gardner, 2000). For example, mothers were found to use more positive language and engage more with their child in the presence of a researcher compared with when they were alone with their child (Zegiob, Arnold, & Forehand, 1975).

The Language Environment Analysis (LENA) system uses digital audio-recorders, which are worn in pockets of custom-made children's clothing, to unobtrusively document acoustic environments. LENA enables collecting naturalistic observations of children's language experiences, without observer biases, for up to 16 hours (i.e., full days) and estimates the number of words that the study child has heard from adults, including parents, other relatives and carers, and visitors (Gilkerson & Richards, 2009).

Previous studies that used LENA reported positive associations between the quantity of adult spoken language (i.e., the number of adult spoken words) in the home environment and children's own language ability. For example, Zimmerman et al. (2009) found in a sample of 275 families with children aged 2 to 24 months that each 1000 word increase in adult spoken language corresponded with a 0.44 *SD* gain in Preschool Language Scale scores (PLS-4; Zimmerman, Steiner, & Pond, 2002). Recently, Gilkerson et al. (2018) reported that the quantity of adult spoken language that children were exposed to between the ages of 2 and 47 months accounted for 7% of the variance in their language ability at age 9 to 14 years. These findings are aligned with the *usage-based* theory of language acquisition, whereby an enriched language environment provides more lexical and syntactic examples from which children can construct language (Abbot-Smith & Tomasello, 2006; Tomasello, 2009).

While the association between the quantity of adult spoken language and children's language development is well established (see Head Zauche et al. (2016) for a review), we only identified two previous studies that used LENA to test the relationship between the quantity of adult spoken language and children's cognitive outcomes. The first reported in a sample of 26 preterm infants that the quantity of adult spoken language that the infants experienced at age 36 weeks accounted for 26% of the variance 10 months later in composite scores across five cognitive domains (cognitive, language, motor, social-emotional, and adaptive behaviour; Caskey et al., 2014). The other one is Gilkerson et al.'s (2018) study, mentioned above, which found that the quantity of adult spoken language experienced from 2 to 47 months of age explained only 1% of the variance at the ages of 9 to 14 years in cognitive ability scores derived from five scales (verbal comprehension, visual-spatial, fluid reasoning, working memory, and processing speed). That is, previous estimates of the strength of the association between the quantity of adult spoken language that children are exposed to and their cognitive outcomes vary substantially in naturalistic home observational studies. We speculate that the age at which the cognitive assessments occurred may drive the differences in reported associations. For example, the quantity of adult spoken language may be extremely important for cognitive development in early life, however by childhood and adolescence, other factors such as peer-groups and schooling may become more influential (Cappella & Hwang, 2015; Roberts et al., 2015).

To the best of our knowledge, no previous LENA study has assessed the lexical diversity of adult spoken language (i.e., the number of different words) that children are exposed to in the home environment, or its association with children's language or cognitive outcomes. However, other research that relied on non-naturalistic home observations, with researchers visiting the family home to conduct video- or audio-recordings, have shown that greater lexical diversity of adult spoken language is positively associated with children's language outcomes (Hart & Risley, 1995; Head Zauche et al., 2016; Hoff, 2003; Huttenlocher et al., 2010; Pan et al., 2005). For example, in a sample of 108 children, those who showed greatest gains in lexical diversity from 14 to 36 months had mothers who spoke with a more diverse vocabulary themselves (Pan et al., 2005).

Only one of the aforementioned studies, which assessed adult lexical diversity, also tested children's non-verbal cognitive ability. In Hart and Risley's (1995) longitudinal study of 42 families, maternal lexical diversity correlated .51 with children's cognitive ability at 36 months of age. We also identified a prospective cohort study of 1,292 parent-child dyads, which reported a correlation of .11 between maternal lexical diversity and children's cognitive ability at 15 months of age (Burchinal, Vernon-Feagans, Cox, & Key Family Life Project Investigators, 2008). The discrepancy in the strength of association may be due to differences in the lengths of the observations used to assess lexical diversity: Burchinal et al. (2008) used videotaped observations of mothers reading with their children for up to 10 minutes, whereas Hart and Risley (1995) included 23 full hours of audio-recordings that were collected over the course of 23 months. Because both studies also differed in sample size and observation method (i.e., video versus audio), we can only speculate about the reasons for the differences in effect sizes. The current study extends these earlier findings to test how the quantity and lexical diversity of adult spoken language that children are exposed to in the family home are associated with their cognitive and language outcomes, as well as with parents' literacy behaviours and beliefs.

Parental Literacy Behaviours and Children's Outcomes

Parental literacy behaviours refer to literacy-based activities that parents undertake with their children, such as storytelling and joint book reading, while parental literacy beliefs describe parents' attitudes, perceptions and values regarding children's literacy and language development (Weigel, Martin, & Bennett, 2005). Previous studies have shown positive associations between parents' literacy beliefs and their engagement in literacy activities (Bingham, 2007). For example, parents who value literacy and take an active role in their children's literacy development tend to engage more frequently in child-directed literacy behaviours, such as asking questions during joint book reading, giving feedback, and showing enthusiasm (DeBaryshe, 1995; Sonnenschein et al., 1997). Likewise, parental characteristics, such as the amount of expression, involvement, sensitivity and teaching behaviours that parents display during literacy activities, are also positively associated with parents' literacy beliefs (Bingham, 2007). Furthermore, parents' literacy beliefs have been found to benefit children's language outcomes: For example, parental literacy beliefs accounted for 11% of the variance in children's expressive language skills at the age of 4 years in a sample of 85 families (Weigel et al., 2005).

Children exposed to more parental literacy behaviours at 27 months also had greater expressive language skills at 30 and 42 months (Deckner et al., 2006). Likewise, paternal literacy behaviours at 2 years predicted children's expressive language ability at 4 years (Quach et al., 2018). Furthermore, a meta-analysis of 29 studies found positive effects of joint book reading on children's language outcomes ($d = 0.59$; Bus, van IJzendoorn, & Pellegrini, 1995). In addition, in a sample of 195 language impaired children, aged 59 to 96 months, those with greater familial literacy behaviours also had better expressive and receptive language skills, compared with children whose families engaged in fewer literacy behaviours (Tambyraja, Schmitt, Farquharson, & Justice, 2017).

Only a handful of studies have tested the associations between parents' literacy behaviours and children's cognitive abilities. For example, in a sample of 1046 families, parents' literacy behaviours correlated .21 with children' cognitive ability at 24 months of age (Rodriguez et al., 2009). By comparison, in a sample of 295 families, parents' literacy behaviours were more strongly associated with children's cognitive ability at .53, when they were aged 58 months and above (Griffin & Morrison, 1997).

In summary, previous research suggests that parents' literacy behaviours and beliefs are positively associated with children's cognitive and language outcomes. However, the strength of these associations has not been directly tested using naturalistic observations of children's language ability. Furthermore, it is unknown how parents' literacy behaviours and beliefs are related to the quantity and lexical diversity of adult spoken language, which also informs children's cognitive and language outcomes.

The Current Study

The current study uses data from 107 British families to compare the relative contributions of the quantity and lexical diversity of adult spoken language and of parental literacy behaviours and beliefs in the family home to children's cognitive and language outcomes. Because specific cognitive abilities, such as problem solving, memory and attention, are not clearly differentiated and operationalised in early life but constitute generic processes, we used the broad terms of cognitive abilities, development and outcomes when assessing and discussing children's non-verbal cognition (Elliot, 1990; Saudino, 1998). According to constructivist approaches, language recruits domain-general learning mechanisms and thus, language and cognitive abilities are inter-related (Kidd, Donnelly, & Christiansen, 2018). However, within this framework there is scope for the notion that non-verbal cognitive abilities may also be distinct from verbal abilities; therefore, both kinds of abilities were assessed in the current study (Deák, 2014; Kidd et al., 2018).

We hypothesised that (a) the quantity and lexical diversity of adult spoken language will be positively associated with parents' literacy behaviours and beliefs, so that families where children are exposed to more and more diverse language also experience greater literacy behaviour engagement. We also hypothesised that (b) the quantity and lexical diversity of adult spoken language and parents' literacy behaviours and beliefs will be positively associated with and each make an independent contribution to children's language and cognitive outcomes. Finally, and although previous estimates produced a wide range of effect sizes, we predicted that (c) the quantity and lexical diversity of adult spoken language will be more strongly associated with children's cognitive and language outcomes than parents' literacy behaviours and beliefs, because adult spoken language is a more permanent and enduring experience in the family home than parents' literacy behaviours and beliefs, which become salient only occasionally during the day.

4.3 Method

Sample

Initially, 225 families (236 children) that resided in Southeast London, were recruited via advertisements in nurseries (*n* = 59), on Facebook (*n* = 141), through word-of-mouth (*n* = 15) or on the authors' lab website (n = 10). Of the 220 families who were eligible (i.e., monolingual English-speaking families with a typically developing child aged 24 to 48 months), 131 families completed a 1-hour online survey and subsequently received the study materials. Out of these, 107 families audio-recorded three days of interactions in their home environments for more than 5 hours per day. In six families, two children (i.e., 2 siblings and 4 twin pairs) participated in the study: To ensure the independence of observations, one sibling was randomly excluded from the analyses. For a more detailed description of the sample see d'Apice, Latham and von Stumm (2019).

The final analysis sample consisted of 107 typically developing children (mean age in months = 32, *SD* = 6.5, range = 24 to 48; 51 girls), 105 mothers (mean age in years = 37, *SD* = 4.6, range = 22.5 to 51.6), and 73 fathers (mean age in years = 39, *SD* = 5.2, range = 25.2 to 55.1). The vast majority of parents were born in Britain, with English as their native language (86% and 99% respectively), and on average they had spent 33.42 years in the UK (*SD* = 10.9, range from 0 to 55). Regarding the mothers, 28 were full-time parents; 58 were in part-time and 11 in full-time employment; 4 identified as students, and 4 were on maternity leave. By comparison, 59 of the fathers were in fulltime and 10 in part-time employment, and 4 were full-time parents. Most parents had university degrees (86% of mothers and 78% of fathers) and were married co-parents (96%), most whom had been living together for 4 or more years (92%). 54% of the children had siblings living in the same household. Families varied in socio-demographic background, but they were on average of higher socioeconomic status than the general British population.

Procedure

The study was approved by the Ethics Committee at Goldsmiths, University of London. This study conforms to the ethical principles detailed in the Declaration of Helsinki. All participants (or their legal guardians) gave their informed consent and children gave their assent prior to their inclusion in the study. Data were collected between November 2014 and August 2016.

Initially, parents completed an online survey reporting on their socio-demographic information, literacy behaviours and beliefs, and child's characteristics. After survey completion, study materials including (a) 3 LENA digital audio-recorders (details below), (b) 3 items of LENA clothing, and (c) a

Parent Report of Children's Abilities (PARCA) booklet (details below) were hand-delivered to each family. Parents independently conducted audio-recordings on 3 days when they were mainly at home, to ensure the clarity and viability of the recordings. 10 families recorded on consecutive days, although on average, recordings were conducted within a time period of 16 days (*SD* = 16; range = 2 to 92). The parents also administered the PARCA booklet to their child at home. Each family received a child's LENA t-shirt and 79 families also received £50 in cash for their participation. Differences in compensation were due to changes in the study's funding. There was no difference in demographics or any of the measured variables between those families that did and did not receive monetary compensation.

Measures

Parental literacy behaviours.

Literacy activities. Parents reported 8 literacy-related activities, 7 of these items were selected from Bennett, Weigel, and Martin's (2002) scale and supplemented with an additional item: "How often do you read to yourself for pleasure?" from DeBaryshe and Binder (1994; complete measures are shown in the supplemental material). These 8 items assessed how often parents and children engage with literacy activities such as reading aloud, reciting nursery rhymes, storytelling and playing language games on a 6-point Likert scale (1 = *hardly ever*, 2 = *monthly*, 3 = *once every fortnight*, 4 = *weekly*, 5 = *every other day*, 6 = *daily*).

Literacy practices. Parents' literacy practices were measured using a 4-item scale. Two of the items were selected from Bennett et al. (2002): "How many minutes per day do you spend reading to your child?", rated on a 5-point scale (1 = *not a minute*, to 5 = 20 *minutes or more*), and "how often does your child see you read?", rated on a 6-point scale (1 = *never*, to 6 = *more than once a day*). The remaining two items were developed by DeBaryshe and Binder (1994): "How many books does your child own?" and "how old was your child (in months) when you started to read to him or her?"

Literacy beliefs. Parents' literacy beliefs were measured on 18 items, selected from the Parent Reading Belief Inventory (PRBI; DeBaryshe & Binder, 1994). Literacy beliefs are organised into four distinct subscales: 1) Affect: Measures positive affect associated with reading, 2) Verbal Participation: Measures parents' intentions to elicit verbal responses from their child during reading, 3) Knowledge: Measures parents' belief in the importance of reading to improve children's morals and world knowledge, and 4) Resources: Measures the parents practical capacity to participate in reading (DeBaryshe & Binder, 1994). All literacy belief items were rated on a 5-point Likert scale (1 = *strongly disagree*, 2 = *disagree*, 3 = *don't know*, 4 = *agree*, and 5 = *strongly agree*). The *affect* subscale was composed of 6 items, such as "reading with my child is a special time that we love to share". The *verbal participation* subscale included 5 items, such as "I ask my child a lot of questions when we read". Likewise, the *knowledge* subscale encompassed 5 items, such as "reading helps children learn about things they never see in real life (like Eskimos and polar bears)". The *resources* subscale was composed of two items: "even if I would like to, I'm just too busy and too tired to read to my child" and "I don't read to my child because I have other, more important things to do as a parent".

Language.

Adults' word counts. The children "wore" the small, lightweight LENA digital audio-recorders in the front pockets of specifically manufactured clothing, such as t-shirts and dungarees. These audio-recorders recorded all sounds within a six-foot radius of the study child for up to 16 hours per day. The audio-recordings were processed using the LENA Pro software version V3.4.0–143, which extracted the number of adult spoken words on each recording day (LENA Research Foundation, 2012).

Adults' and children's lexical diversity. We selected two 5-minute audio excerpts per day that registered the highest number of conversational turns (i.e., an adult-child interaction in which one speaker initiates a conversation and the other responds within five seconds) between 8am and 11am, and between 5pm and 8pm (i.e., two per day for 3 days, resulting in six 5-minute excerpts per family). These audio excerpts were transcribed by professional typists according to the Codes for the Human Analysis of Transcripts (CHAT; MacWhinney, 2000), and subsequently proofread and corrected by two trained research assistants.

To calculate a family's adult lexical diversity score, we combined the 6 transcripts per family and assigned the same identifier code to all adult speakers within the family. The transcripts were then analysed using the VOCD command in Computerized Language Analysis (CLAN; MacWhinney, 2000) and D scores, a measure of lexical diversity, were computed (see supplemental material for details on D scores). Likewise, we computed D scores for each child by subjecting their combined transcripts to CLAN analysis.

Children's cognitive ability. The Parent Report of Children's Abilities (PARCA) assesses children's non-verbal cognitive ability. For the current study, we selected 54 items from the PARCA versions for children aged 2, 3 and 4 years (Oliver et al., 2002; Saudino et al., 1998). First, parents reported via the online survey whether their child could perform a set of 28 activities, for example "can your child stack three small blocks on top of each other by themselves?" Possible responses included *yes*, *no*, and *I don't know*. PARCA parent report ratings were then summed. Second, parents administered a PARCA testing booklet to their child at home, which was specifically designed to assess non-verbal cognitive abilities and therefore, the test instructions had minimal reliance on children's ability to understand spoken instructions (Oliver et al., 2002). The booklet was composed of 9 drawing, 7 copying and 10 matching tasks, which were independently scored by two research assistants, according to the test's scoring guidelines (Oliver et al., 2002; Saudino et al., 1998). Initial agreement rate of 92.9%, rose to 100% after differences were resolved through discussion with reference to the scoring guidelines.

The parent-report and parent-administered sections of the PARCA corresponded to scores from the Bayley Scales of Infant Development Mental Development Index in a sample of 107 two-year olds (BSID-II MDI; Bayley, 1993; $r = .39$, $p < .001$ & $r = .27$, $p < .01$ respectively; Saudino et al., 1998) and were also validated against the McCarthy Scales of Children's Abilities (McCarthy, 1972; Oliver et al., 2002; Saudino et al., 1998). Furthermore, the PARCA-R (revised, with additional items) was validated against the BSID-II and BSID-III MDI in two samples ($N = 64$ and 204) of 24-month-old preterm infants ($r = .54$, $p < .001$; Johnson et al., 2004; and $r = .43$, $p < .001$; Martin et al., 2013, respectively).

Socioeconomic status (SES). Families reported three markers of SES via the online survey: (1) Educational attainment: Each parent stated the highest educational qualification they had obtained, ranging from school leaving certificate, national vocational qualification, undergraduate degree to postgraduate degree. (2) MacArthur Scale of Subjective Social Status (Adler, Epel, Casellazzo & Ickovics, 2000): The following instructions were displayed alongside a drawing of a ladder with 10 rungs "think of this ladder as representing where people stand in our society. At the top of the ladder are the people who are the best off, those who have the most money, most education, and best jobs. At the bottom are the people who are the worst off, those who have the least money, least education, and worst jobs or no job." Parents were asked to place an X on the rung that best represented their own SES, with 1 indicating low and 10 high SES. The MacArthur scale has previously been validated against a composite of income, education and occupation ($r = .40$, $p < .01$, $N = 157$; Adler et al., 2000), and a composite of education and occupation ($r = .53$, $p < .01$, $N = 177$; John-Henderson, Jacobs, Mendoza-Denton, & Francis, 2013). (3) Overcrowding index: Parents reported the number of people and the number of rooms in their household, excluding the bathroom, kitchen or box room (a small, often windowless room that is usually used for storage). An overcrowding index was calculated for each family by dividing the number of rooms in the home by the number of people in the household so that a higher score represented less overcrowding.

Statistical Analysis

As our language measures were assessed at the family level, we also assessed literacy behaviours and beliefs at the family level rather than per parent. Thus, we summed mothers' and fathers' literacy behaviours in each family, and adjusted the sum by the number of parents who provided data.

We reverse-coded several literacy behaviour items, including "how old was your child when you started to read to him or her?", so that younger ages indicated higher literacy scores. We also reverse-coded two items from both the affect and the resources subscales, so that all scores indicated greater literacy behaviours. Next, we *z* transformed each of the four literacy practices items, as they included open-ended responses and therefore standardising these items allowed for comparison with the other literacy behaviour items. For each of the literacy behaviour domains (i.e., activities, practices, and the belief subscales; affect, verbal, knowledge and resources), we calculated a mean average score per family.

Because the literacy belief subscales were highly inter-correlated (Table 3.2), we calculated a total literacy beliefs score per family by summing their average scores from each subscale (Table 3.1), which has also been done in other studies (Curenton & Justice, 2008; Weigel, Martin, & Bennett, 2006). Because the correlations between family-level literacy measures were high (details below) and to avoid issues of multicollinearity, a composite literacy index was built by *z* transforming and summing the mean scores for literacy activities, practices and beliefs.

SES was indexed by three markers, educational attainment, subjective social status and an overcrowding index. The scores from each SES marker were *z* transformed and summed, with the emerging index score being adjusted for the number of markers available per family (e.g., information from both parents).

Regarding the PARCA booklet, one of our measures of children's cognitive ability, composite scores for the three sections of the PARCA booklet (i.e., drawing, copying and matching), which correlated .33, .42, and .51, were calculated, *z* transformed and summed. To evaluate the relative contributions of adult spoken language and parents' literacy behaviours on children's cognitive and language outcomes, we fitted separate regression models with SES, literacy index, adults' word counts and adults' lexical diversity as simultaneous predictors for the PARCA booklet scores, the PARCA parent report and children's lexical diversity. These three outcomes were adjusted for child age and gender.

4.4 Results

The descriptive statistics for family level variables are displayed in Table 3.1 (see Table 4.1 for the descriptive statistics per parent, and Table 4.3 for raw PARCA booklet scores). Table 3.2 displays correlations between all study variables (see Table 4.2 for correlations per parent). The correlations between literacy activities, practices and beliefs ranged from .38 to .50, and we therefore built a composite score for all three measures, termed the literacy index (Table 3.2). The literacy index correlated moderately (i.e., .26 to .31) with children's cognitive ability and lexical diversity, as did the number of adults' words (i.e., .17 to .35) that children were exposed to. By comparison, adults' lexical diversity was more weakly associated with children's outcomes (i.e., −.02 to .28; Table 3.2).

The literacy index correlated .33 with adults' word counts but was less strongly associated with adults' lexical diversity (i.e., .06). There was no association between adults' word counts and adults' lexical diversity (i.e., −.01).

In the regression models (Table 3.3), the literacy index accounted independently for 4% and 5% of the variance in PARCA scores and parent-reported cognitive ability, although the regression model for parent-reported cognitive ability did not reach significance (p = .08). The literacy index did not account for any variance in children's lexical diversity. The number of adults' words was associated with the PARCA scores, accounting for 11% of the variance, but not with parent-reported cognitive ability or children's lexical diversity. By contrast, adults' lexical diversity explained 12% of the variance in children's lexical diversity but was not related to either the PARCA scores or parent reported

Table 3.1

Descriptive Statistics of Family-Level Variables

		Mean	*SD*	Minimum	Maximum	α
Literacy activities		4.15	0.67	2.19	6	0.59
Literacy practices		0.01	0.51	-2	1.3	0.66
Literacy beliefs	Affect	4.76	0.26	3.67	5	0.70
	Verbal	4.08	0.48	2.4	5	0.62
	Knowledge	4.41	0.33	3.4	5	0.61
	Resources	4.61	0.61	1.5	5	0.05
	Total	4.46	0.27	3.72	4.97	0.63
Literacy index		0	2.38	-8.5	5.01	0.71
Adults' word counts[a]		18021.70	5769.53	5533.08	33441.89	-
Adults' lexical diversity[b]		46.05	13.78	-8.79	74.04	-
SES index		-0.02	0.56	-1.69	0.95	-
Children's lexical diversity[b]		26.42	20.78	-22.18	84.67	-
PARCA booklet[c]		0	0.78	-1.82	1.62	0.65
PARCA parent report		19.46	3.3	12	27	0.72

Note. α = Cronbach's alpha. Variables corrected for [a] recording duration, [b] number of available recordings. [c] N = 104.

Table 3.2

Pairwise Correlations between Family Literacy Measures and Children's Outcomes

		1	2	3	4	5	6	7	8	9	10	11	12	13	14
	1. Adults' word counts	-													
	2. Adults' lexical diversity	-.01	-												
	3. SES index	.11	.18	-											
	4. Literacy activities	.23*	.06	.15	-										
	5. Literacy practices	.22*	-.02	.19*	.45***	-									
Literacy beliefs	6. Affect	.23*	-.05	.04	.35***	.30**	-								
	7. Verbal	.21*	.12	-.03	.44***	.32***	.40***	-							
	8. Knowledge	.27**	.04	.12	.43***	.28**	.44***	.48**	-						
	9. Resources	.26**	.18	.06	.11	.10	.19*	.03	.22*	-					
	10. Total	.34***	.10	.05	.50***	.38***	.72***	.80***	.78***	.40***	-				
	11. Literacy index	.33***	.06	.16	.82***	.77***	.57***	.65***	.63***	.26**	.79***	-			
	12. Child lexical diversity	.17	.28**	.24*	.37***	.20*	.02	.01	.05	.10	.05	.26**	-		
	13. PARCA book	.35***	-.02	.08	.30**	.30**	.09	.15	.08	-.02	.13	.31**	.46***	-	
	14. PARCA parent report	.13	-.15	.07	.30**	.24*	.12	.04	.20*	-.08	.10	.27**	.43***	.49***	-
	15. Child age	.06	-.14	-.06	.07	.17	.01	-.01	-.01	-.07	-.02	.09	.40***	.66***	.55***

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

Table 3.3

Regression Models for Children's Outcomes

	PARCA book[cd]					PARCA parent report[c]					Children's lexical diversity[c]				
	B	*SE B*	β	95% CI		*B*	*SE B*	β	95% CI		*B*	*SE B*	β	95% CI	
SES index	.02	.17	.01	-.32	.36	.21	.18	.12	-.14	.56	**.37**	**.16**	**.21**	**.05**	**.68**
Literacy index	**.09**	**.04**	**.20**	**.00**	**.17**	**.09**	**.04**	**.22**	**.01**	**.18**	.06	.04	.13	-.02	.13
Adults' word counts[a]	**.14**	**.04**	**.33**	**.06**	**.22**	.00	.04	.01	-.08	.09	.03	.04	.08	-.04	.11
Adults' lexical diversity[b]	.10	.09	.10	-.08	.27	-.11	.10	-.12	-.30	.08	**.33**	**.09**	**.34**	**.16**	**.51**
R^2	.18					.04					.20				
F	6.49					2.12					7.56				
p	< .001					.08					< .001				

Note. Variables corrected for [a] recording duration, [b] number of available recordings, [c] age and gender. [d] $N = 104$. Predictors significant at $p < .05$ are shown in bold.

cognitive ability. Finally, SES accounted for 4% of the variance in children's lexical diversity but was not associated with either the PARCA scores or parent-reported cognitive ability.

Overall, our results show that the literacy index was moderately associated with the quantity of adult spoken language that children were exposed to and independently predicted children's cognitive ability. In addition, we found that the quantity of adult spoken language predicted children's cognitive outcomes, whereas the lexical diversity of adult spoken language predicted their language outcomes.

4.5 Discussion

We sought to compare the influence of parents' literacy behaviours and beliefs with the quantity and lexical diversity of adult spoken language on children's cognitive and language outcomes using data from naturalistic home observations. The key finding from this study is that parents' literacy behaviours and beliefs were moderately, positively associated with the quantity of adult spoken language, suggesting that parents who expose children to more adult words also engage in more literacy behaviours and hold stronger literacy beliefs. Furthermore, we observed that parents' literacy behaviours and beliefs predicted children's cognitive outcomes, independent of the adult spoken language that children experienced in the family home. That said, adult spoken language accounted for almost three times more of the variance in children's cognitive outcomes than parents' literacy behaviours and beliefs did (i.e., 11% compared to 4%). Regarding this difference in effect size, spontaneous adult spoken language is a daylong endeavour, whereas parents' literacy behaviours only occur for relatively short periods of time during the day. Thus, it is plausible that adult spoken language has a more pronounced influence on children's cognitive outcomes than parents' literacy behaviours and beliefs.

We are the first to report associations between parents' literacy behaviours and beliefs, and everyday naturalistic adult spoken language in the home environment. We hypothesised that the quantity and lexical diversity of adult spoken language would be positively associated with parents' literacy behaviours and beliefs. Confirming our first hypothesis, we found a moderate, positive association between parents' literacy behaviours and beliefs and the quantity of adult spoken language. This association may be due to a common cause, for example because well-educated professional parents tend to speak more with their children and also engage in more literacy behaviours (cf. Korat & Haglili, 2007;

Topping et al., 2013). However, we found no association between parents' literacy behaviours and beliefs, and the diversity of adult spoken language that children were exposed to during everyday conversations. This finding suggest that parents' literacy behaviours and adults' lexical diversity are independent markers of the home language environment and not just proxies for the same construct.

Although parents' literacy behaviours were associated with the quantity of adult spoken language, no associations were found with adults' lexical diversity which may result from differences in the lengths of observation. The quantity of adult spoken language was measured over the course of 3 full days, whereas the assessment of adults' lexical diversity was based on six 5-minute recording excerpts (i.e., 30 minutes per family). Although previous studies suggest that adults use more diverse language when engaging in literacy-related behaviours (Mol et al., 2008; Saracho, 2017), we found no relationship between the lexical diversity of everyday adult spoken language in a family and parents' literacy behaviours and beliefs. It is possible that the positive effect of literacy behaviours and beliefs on adults' lexical diversity is limited to the times when adults are actively engaged in literacy, rather than resulting in a systematic long-term increase of adults' lexical diversity. However, our study design did not allow testing this hypothesis.

In their review, Head Zauche et al. (2016) question whether literacy behaviours and beliefs uniquely predict children's language and cognitive outcomes, or if adult spoken language confounds and accounts for these associations. We found here, in line with our second hypothesis, that parents' literacy behaviours and beliefs were unique predictors of children's cognitive outcomes, independent of the everyday adult spoken language that occurred in the family home. It has been suggested that parents who exhibit literacy behaviours and beliefs ask their children more open-ended, complex questions during literacy activities that encourage the child to solve problems and develop their cognitive skills (Rodriguez et al., 2009; Saracho, 2017). Furthermore, literacy behaviours expose children to concepts rarely encountered in everyday life and therefore stimulates understanding of the semantic relations between things. Our findings are aligned with the neuroconstructivist theory of brain development, which posits the dynamic interplay between experience and neural networks that results in improved cognitive performance (Westermann, Thomas, & Karmiloff-Smith, 2010).

Unlike previous research (Deckner et al., 2006; Quach et al., 2018), we found no association between parents' literacy behaviours and beliefs and children's language outcomes. This discrepancy in findings might be due to two reasons. First, our assessment of parents' literacy behaviours and beliefs was more comprehensive than in other studies that solely focused on shared book reading. Second, it is plausible that measuring children's receptive rather than expressive language will result in stronger associations with literacy behaviours, although the aforementioned studies contradict each other on this point. Alternatively, it is also plausible that measures of child language development that assess children's syntax rather than their vocabulary ability may show associations with parental literacy behaviours and beliefs. In line with previous studies (e.g., Caskey et al., 2014; Gilkerson et al., 2018; Hart & Risley, 1995), we found that the quantity of adult spoken language was associated with children's cognitive ability, at least when assessed by the PARCA booklet but not when the parents reported on their offspring's cognitive abilities. The correlation between parent reports and children's booklet test scores was .49 in the current study, which is comparable to .40 reported in previous studies (e.g., Saudino et al., 1998), suggesting that our assessment of children's cognitive ability was reliable. However, parents are likely to be more biased in rating their child's cognitive ability compared to the PARCA booklet, which objectively captures a child's performance level.

In line with some previous studies but not others (Gilkerson et al., 2018; Greenwood, Thiemann-Bourque, Walker, Buzhardt, & Gilkerson, 2011; Pan et al., 2005; Ramírez-Esparza, García-Sierra, & Kuhl, 2014; Zimmerman et al., 2009), we found no association between the quantity of adult spoken language and children's language outcomes. This may be because we did not differentiate between child-directed and overheard speech, although previous research has highlighted the importance of child-directed speech in language learning (Ramírez-Esparza et al., 2014; Rowe, 2012).

Our third hypothesis stated that the quantity and lexical diversity of adult spoken language will be more strongly associated with children's cognitive and language outcomes than parents' literacy behaviours and beliefs. We did find this to be the case, which may be due to the length of time that families spend engaging in conversations compared with literacy behaviours. Notwithstanding, we found evidence that parents' literacy behaviours are independently associated with children's cognitive ability, suggesting that they may be a good target for interventions (Noble et al., 2018).

Limitations

Our study has many strengths but also some limitations. First, our measure of literacy behaviours was derived from parental reports and as such may be biased. We implore future studies to assess parental literacy behaviours from naturalistic observations, although this method will not allow assessment of the literacy beliefs that drive literacy behaviours (Bingham, 2007). Second, our measure of the quantity of adult spoken language neither differentiates parents from other adults, nor overheard from child-directed spoken language. That said, our measure assessed all adult spoken words that children were exposed to throughout the day and thus, comprehensively reflects children's natural language environments. Third, our sample had a restricted SES range and therefore, it was not representative of the general population. However, associations between adult spoken language and parental literacy behaviours with children's outcomes should exist regardless of SES, although we encourage future research to sample more diverse families. Fourth, our cross-sectional design precludes inferring causality or directionality. Longitudinal studies are needed to clarify whether, for example, more intelligent children evoke more literacy behaviours from their parents or vice versa.

4.6 Conclusion

For the first time, we compared the influence of parents' literacy behaviours and beliefs, and adult spoken language on children's cognitive and language outcomes in data from unobtrusive daylong naturalistic audio-recordings. We found positive associations between adult spoken language and children's cognitive and language outcomes. Furthermore, we showed that parents' literacy behaviours accounted for a significant proportion of the variance in children's cognitive outcomes, independent of the adult spoken language in the family home.

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5 Paper 2: Supplemental Material

5.1 Literacy Items

Literacy Activities

Scale: 1 = *hardly ever*; 2 = *rarely*; 3 = *about once every fortnight*; 4 = *about once a week*; 5 = *at least twice a week*; 6 = *at least once each day*.

1. How often do you read to yourself for pleasure?
2. How often do you read aloud from a book or story to your child?
3. How often do you read or look at picture books with your child?
4. How often do you recite nursery rhymes with your child?
5. How often do you tell your child a story or fairy tale from memory?
6. How often do you draw pictures of letters or words with your child?
7. How often do you play games with your child that involve letters or spelling?
8. How often do you do language exercises with your child, for example practicing certain sounds or words?

Literary Practices

1. How many minutes per day do you spend reading to your child?

Scale: 1 = *not a minute*; 2 = *up to 5 minutes*; 3 = *up to 10 minutes*; 4 = *up to 15 minutes*; 5 = *20 minutes and more*.

2. How often does your child see you read, for example a book, magazine or the papers?

Scale: 1 = *never*; 2 = *once a month*; 3 = *once a week*; 4 = *every other day*; 5 = *once every day*; 6 = *more than once a day*.

3. How old was your child (in months) when you started to read to him or her?

   Open ended response.

4. How many books does your child own?

   Open ended response.

Literacy Beliefs

Likert scale: 1 to 5 from *strongly disagree* to *strongly agree*. Items taken from DeBaryshe & Binder, 1994 (42 in original). Items were excluded because (a) they are not applicable to the sample, (b) to shorten the overall scale, and (c) made reference to other things than reading.

Affect.

1. Reading with my child is a special time that we love to share.

2. When we read I try to sound excited so my child stays interested.
3. My child does not like to be read to.
4. I find it boring or difficult to read to my child.
5. I enjoy reading with my child.
6. I want my child to love books.

Verbal participation.

1. When we read, I want my child to help me tell the story.
2. I ask my child a lot of questions when we read.
3. Reading helps children be better talkers and better listeners.
4. When we read we talk about the pictures as much as we read the story.
5. When we read, I want my child to ask questions about the book.

Knowledge.

1. My child learns lessons and morals from the stories we read.
2. Reading helps children learn about things they never see in real life (like Eskimos and polar bears).
3. My child learns important life skills from books (like how to follow a cooking recipe, how to protect themselves from strangers).
4. Stories help build my child's imagination.
5. My child knows the names of many things he or she has seen in books.

Resources.

1. Even if I would like to, I'm just too busy and too tired to read to my child.
2. I don't read to my child because I have other, more important things to do as a parent.

5.2 Results Split by Parent Gender

Descriptive statistics of literacy measures for mothers and fathers separately are displayed in Table 4.1. Correlations of all study variables split by parent gender are displayed in Table 4.2.

Table 4.1

Descriptive Statistics of Literacy Measures for Mothers and Fathers

		Mothers (N = 105)					Fathers (N = 73)				
		Mean	*SD*	Min	Max	α	Mean	*SD*	Min	Max	α
Literacy Activities	(n = 8)	4.27	0.76	2.5	6	0.57	3.95	0.81	1.62	5.38	0.61
Literacy Practices	Frequency of child seeing parent read	4.28	1.83	1	6	-	3.86	1.87	1	6	-
	Frequency of reading with child	4.20	0.85	2	5	-	3.81	1	1	5	-
	Age (months) started to read with child	3.23	3.83	0	24	-	5.97	5.12	0	24	-
	Number of books child owns	73.50	42.47	15	250	-	78.46	57.22	0	300	-
	Practices composite (n = 4)	0	0.61	-2	1.3	0.43	0.02	0.57	-1.25	1.36	0.36
Literacy Beliefs	Positive affect (n = 6)	4.8	0.25	4	5	0.58 [a]	4.67	0.42	3	5	0.81 [a]
	Verbal participation (n = 5)	4.09	0.57	2.4	5	0.62	4.05	0.57	3	5	0.68
	Knowledge (n = 5)	4.44	0.37	3.4	5	0.56	4.34	0.41	3	5	0.65
	Resources (n = 2)	1.30	0.60	1	4.5	0.55	1.44	0.57	1	3	0.36
	Beliefs Composite (18)	4.49	0.29	3.72	5	0.74	4.39	0.38	3	5	0.86

Note. α = Cronbach's alpha. [a] Maternal and paternal positive affect differ because most mothers reported their child likes being read to.

Table 4.2

Pairwise Correlations of Study Variables, Split by Parent Gender

	1	2	3	4	5	6	7	8	9	10	11	12	13	14
1. AWC	-	-.01	.11	.06	.13	.17	.22	.19	-.18*	.27	.13	.35	.13	.06
2. ALD	-.01	-	.17	.06	-.03	-.17	.12	-.01	-.09	.04	.28	-.03	-.15	-.14
3. SES index	.11	.17	-	.11	.15	-.08	-.04	.08	.00	-.02	.22	.08	.07	-.06
4. Activities	.30**	-.02	.15	.19	.37*	.26*	.33*	.28	-.07	.37*	.30	.22	.25	.00
5. Practices	.31*	.05	.28	.49***	.33**	.33	.34	.27	-.05	.39	.18	.34	.28	.21
6. Beliefs A	.19	.02	.17	.31**	.16	.14	.34*	.44***	-.08	.65***	-.10	.01	.09	.01
7. Beliefs V	.12	.07	.09	.32	.20	.52***	.07	.50***	-.06	.83***	.11	.19	.12	.02
8. Beliefs K	.26	.08	.24	.34**	.26*	.59***	.60***	.04	-.17	.79***	-.03	-.04	.16*	-.05
9. Beliefs R	-.30**	-.13	-.13	-.51***	-.37***	-.56***	-.25*	-.42***	.26*	.35	-.04	.09	.10	.12
10. Beliefs T	.25	.08	.19	.43*	.30	.85***	.82***	.83***	.60***	.00*	.03	.07	.12	-.03
11. CLD	.13	.28	.22	.23	.24	.00	-.12	.12	-.13	.01	-	.45**	.43**	.41**
12. PARCA book	.35	-.03	.08	.26	.16	.07	-.04	.19	-.08	.08	.45**	-	.49***	.66***
13. Parent report	.13	-.15	.07	.14	.04	.05	-.23	.07	-.02*	-.05	.43**	.49***	-	.55***
14. Child age	.06	-.14	-.06	.04	-.02	-.07	-.22*	-.06	-.07*	-.12	.41**	.66***	.55***	-

Note. AWC = adults' word counts, ALD = adults' lexical diversity, Beliefs; A = affect, V = verbal, K = knowledge, R = resources, T = total, CLD = children's lexical diversity. * $p < .05$, ** $p < .01$, *** $p < .001$. Mothers are above the diagonal and fathers below; the diagonal shows inter-correlations.

5.3 Lexical Diversity: D Scores

D scores are based on the probability of new vocabulary being introduced into progressively longer samples of speech (Malvern, Richards, Chipere, & Durán, 2004). McKee, Malvern, and Richards (2000) describe how D scores are computed: Within a speech sample, as the token size (i.e., the number of words) increases, the ratio between the number of tokens and types (i.e., different words used) decreases. As the type token ratio (TTR) falls in a predictable manner in all speech samples, a theoretical mathematical model is used to model the lexical diversity of speakers. To obtain D scores for each speaker, the VOCD command in CLAN first plots a TTR x token curve for each token size from 100 trials of randomly chosen words without replacement throughout the speech sample. The program then uses a curve-fitting procedure that finds the best fit between the theoretical model and the empirical data by adjusting values for D. The resulting D score is therefore an estimation of the lexical diversity of the speaker.

D scores have several advantages over other measures of lexical diversity such as the type token ratio. Notably, D scores are not a function of the number of words in a sample and therefore are comparable across speakers and studies (McKee et al., 2000). This feature ensures all data within a sample is used, by contrast, researchers using type token ratios often truncate their data to a particular token size to allow valid comparisons across their participants (McKee et al., 2000).

5.4 PARCA Booklet Raw Scores

The Parent Report of Children's Abilities (PARCA) assesses children's non-verbal cognitive ability. The booklet was composed of 9 drawing, 7 copying and 10 matching tasks. The raw scores for each task and total scores, before standardising or adjusting for age and gender, are displayed in Table 4.3.

Table 4.3

Raw Scores for PARCA Booklet

PARCA task	Mean	*SD*	Minimum	Maximum	Possible maximum score	α
Drawing	2.87	1.42	1	7	14	.62
Copying	6.60	2.50	0	10	10	.82
Matching	5.27	2.86	0	10	10	.80
Total	14.74	5.38	2	25.50	34	.65

Note. *N* = 104. α = Cronbach's alpha.

5.5 Supporting References

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6 Paper 3: Does Age Moderate the Influence of Early Life Language Experiences? A Naturalistic Home Observation Study

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6.1 Abstract

We explored if children's age moderated associations between their early life language experiences and their linguistic and cognitive skills. For 107 British children, aged 24 to 48 months, and their families, we collected 3 day-long audio-recordings of their naturalistic home environments (*M* = 15.06 hours per day, *SD* = 1.87). Children's cognitive ability was assessed by parent-ratings and with a cognitive testing booklet that children completed at home. We found that the quantity, lexical diversity and vocabulary sophistication of adult speech were associated with children's linguistic and cognitive skills. However, these associations were not moderated by children's age. Our findings suggest that the influence of early life language experience is not differentiated at ages 24 to 48 months.

6.2 Introduction

Children’s exposure to adult speech in early life is thought to be pivotal for their own language and cognitive development (Caskey, Stephens, Tucker, & Vohr, 2014; Hart & Risley, 1995; Hoff, 2003). In particular, three characteristics of adult speech, including (i) the quantity (d’Apice, Latham, & von Stumm, 2019; Hart & Risley, 1995; Weisleder & Fernald, 2013), (ii) the lexical diversity (Pan et al., 2005), and (iii) the vocabulary sophistication (Rowe, 2012), have been shown to inform children’s language and cognitive development. The influence of these characteristics of adult speech on children’s language and cognitive outcomes has been suggested to vary as a function of children’s age, but corresponding findings are scarce and inconsistent. The current study uses extensive naturalistic home observations to add to the existing body of research on interactions between experience and development, overcoming some of the limitations of previous research in this area.

Children who are exposed to a large quantity of adult speech in the early stages of language acquisition experience multiple repetitions of high-frequency words. These repetitions result in a reduction of processing time for encoding, which aids vocabulary development (Ellis, 2002). After children have built up a basic vocabulary base, exposure to adult speech that is rich in diversity and sophistication helps to further enhance children’s lexicons by introducing them to new and rare words (Jones & Rowland, 2017; Rowe, 2012). Therefore, the quantity of adult speech is likely to influence children's early language acquisition, but as their linguistic competence develops, the lexical diversity and vocabulary sophistication of adult speech becomes more relevant for children's language development. In this case, we would expect for age to moderate the influence of the characteristics of adult speech on children’s language development.

We have identified three previous studies that explored whether children’s age moderates the association between characteristics of adult speech and children’s language. First, Pan and colleagues (2005) videotaped 10-minute interactions of 108 U.S. mother-child dyads in the family home when the child was aged 14, 24 and 36 months. At each observation, mothers could choose from books and age-appropriate toys to use for engaging with their child; the quantity and the lexical diversity of mothers’ speech (i.e., word types) during these interactions was assessed. In a series of multi-level models, the lexical diversity of mothers’ speech was significantly associated with children’s growth in lexical diversity over time. Furthermore, there was a significant interaction between children’s age and their mothers' lexical diversity in the prediction of children's language development. Specifically, at age 14 months, children whose mothers used high levels of lexically diverse speech (i.e., in the 90th percentile) did not differ in their own lexical diversity from children whose mothers spoke with low levels of lexical diversity (i.e., in the 10th percentile). By the age of 24 months, children of high-diversity mothers produced on average 9-word types more than children of low-diversity mothers. But by age 36 months, the difference between children from high- and low-diversity mothers had diminished to 1-word type (Pan et al., 2005), suggesting that the influence of mothers' lexical diversity on their children's lexical diversity is most pronounced around 24 months of age. By contrast to the association between mothers' and children's lexical diversity, Pan et al. (2005) observed no effect of mothers' quantity of words on children's linguistic growth.

In a second, later study, Rowe (2012) reported findings based on analyses of 90-minute video recordings of 50 parent-child dyads undergoing normal daily activities in their homes that were collected at the children's ages of 18, 30 and 42 months. Children's receptive vocabulary was assessed 1 year after each home observation was conducted. Children's growth in receptive vocabulary at age 30 and 54 months was not predicted by either the quantity, lexical diversity or vocabulary sophistication of parents' speech, after controlling for confounding variables. However, at 42 months, the diversity and sophistication of parents' words spoken a year earlier were both significantly associated with children's growth in receptive vocabulary, accounting independently for 9% and 6% of the variance, respectively. These findings are only partially aligned with the previous study's result that the association between mothers' and children's lexical diversity is most pronounced at age 24 months.

The third study that assessed whether children's age moderated associations between adult speech and children's outcomes analysed transcripts from a corpus of natural language data, known as CHILDES (MacWhinney, 2000). In this study, Jones and Rowland (2017) analysed 2-hour long audio-recordings that were collected from 16 mother-child dyads every 3 weeks over the course of one year, starting when the child was 22 months old. The number of words (i.e., the quantity of language input) and the number of word types (i.e., the lexical diversity) that mothers spoke was computed from the transcripts at child ages 22 and 28 months, and child lexical diversity was assessed when they were aged 28 and 33 months. The quantity of mothers' language input at 22 and 28 months was not associated with children's lexical diversity at 28 or 33 months. Likewise, mothers' lexical diversity at children's age of 22 and 28 months was not significantly related to children's gains in lexical diversity at age 28 months. However, five months later (i.e., at age 33 months), mothers' lexical diversity at age 22 and 28 months accounted for 18% and 13% of the variance in children's growth in lexical diversity, respectively. Jones and Rowland (2017) also used computational modelling to hold the quantity of language input constant whilst varying the diversity of input, and then repeated the process but instead varied the quantity and kept the diversity of language input constant. They found that initially the model learnt more lexical items from input with a greater quantity, however this was superseded by a rich diversity of input in the latter stages of learning. The authors suggest that diverse input includes a larger number of phonemes or sub-lexical chunks from which the model is able to extrapolate to newly encountered words.

Overall, the three prior studies reported that adults' lexical diversity predicted children's linguistic growth, but each study identified this association at a different child age. In addition, one study found moderation effects of children's age on the association between adults' vocabulary sophistication and children's linguistic growth. Because the other two studies did not assess this language marker, they could not corroborate the finding.

We propose that the discrepancies in the earlier findings are likely to be due to three factors. First, two of the studies were based on small sample sizes (Jones & Rowland, 2017; Rowe, 2012), which have low power to detect differences in correlation strengths (Asendorpf et al., 2013). This problem affects many studies in language development, because the demand for power conflicts with the high costs in time, effort and funding for collecting data from children for developmental research. As a result, studies on language development have on average 44% statistical power to detect a main effect, far less than the recommended level of study power at 80% (Bergmann et al., 2018). Statistical interaction effects, where the relation between two variables varies as a function of a third, require even more power to be reliably identified (Shieh, 2019). We used G*Power (Faul, Erdfelder, Buchner, & Lang, 2009) to estimate the power for each of the previous three studies for detecting an interaction of small effect size (i.e., R^2 increase of .1) in a multiple regression model. Specifying three predictors (i.e., child age, language characteristic, and their interaction term), with one being tested (i.e., the interaction term), and an alpha level of .05, a sample size of 16 yields a power of 21%, and a sample of 50 has a power of 59%, compared to the recommended level of 80%. A sample of 108 participants, like in Pan et al.'s (2005) study, is associated with power of 90%. We acknowledge that our power calculations are oversimplified, and that even greater sample sizes are likely to be needed to reliably detect interactions (e.g., Gelman, 2018).

A second reason for the previous studies' differences in findings may be their analytical approaches. Pan et al. (2005) used individual growth modelling to test if mothers' lexical diversity influenced a change in children's lexical diversity over time using child age as the measure of time. By comparison, Rowe (2012) and Jones and Rowland (2017) tested associations between mothers' and children's lexical diversity at different ages and then compared the strength of association across ages.

Finally, the studies differed in the methods of observation for collecting data from the parent-child dyads. In two of the studies, a researcher visited the family home and operated a hand-held video-camera to document the parent-child interactions (Pan et al., 2005; Rowe, 2012). It is plausible that observer and social desirability biases influence parents linguistic behaviour when they are aware of being observed (Gardner, 2000; Saini & Polak, 2014; Zegiob, Arnold, & Forehand, 1975). The third study audio-recorded the mother-child dyads in the home, although the authors do not stipulate if a researcher was present to conduct the recordings.

The Current Study

Studies with larger sample sizes that specifically test for interactions in datasets obtained from observations that eliminate biases are imperative to further our understanding of factors that influence children's language development (Purpura, 2019). We report here data from a sample 107 family-child dyads, which affords adequate power and is the largest naturalistic home observational study of British families to date. We unobtrusively audio-recorded 107 families with the Language Environment Analysis (LENA) system (LENA Research Foundation, 2012). Each family completed 3 full days of audio-recordings and had at least one child aged 24 to 48 months, capturing a wide window of development. Our study design also affords more power than previous research, because our daylong observation period is much larger than those available in previous studies.

Extending previous work, we assessed multiple markers of children's cognitive and language outcomes and of their early life language experiences. In contrast to previous studies in this area that predominantly focused on the role of maternal speech, we included all adult speakers in our analysis to provide a realistic view of children's natural language experiences in the family home (Ramírez-Esparza, García-Sierra, & Kuhl, 2014). Also, by contrast to the previous studies, our sample was only assessed once in time with the participating children ranging in age from 24 to 48 months. We therefore model contemporaneous associations between the characteristics of adult speech and children's verbal and cognitive skills and test if these associations vary as a function of child age.

We hypothesised that the association between the quantity of adult speech and children's language would not be moderated by children's age because none of the previous studies found such an interaction. However, we expected to find that the relation between lexical diversity and vocabulary sophistication of adult speech with children's language outcomes to vary as a function of children's age. With regards to children's non-verbal cognitive outcomes, our analyses were exploratory.

6.3 Method

Sample

The sample comprised 107 monolingual English families with a typically developing child aged 24 to 48 months, including 105 mothers (mean age in years = 37.11, *SD* = 4.56, min = 24.48, max = 51.57), 73 fathers (mean age in years = 39.49, *SD* = 5.16, min = 25.24, max = 55.09), and 107 children (mean age in years = 2.77, *SD* = 0.55, min = 2.03, max = 3.99; 51 girls; full details on recruitment and attrition figures are reported in d'Apice et al., 2019). Most parents were native English speakers and had been born in Britain (99% and 86% respectively). The majority of mothers (58) were in part-time employment, 28 were full-time parents, 11 were employed full-time, 4 were on maternity leave, and 4 were students. For the fathers, 59 were in full-time employment, 10 in part-time roles and 4 were full-time parents. The majority of parents were married (96%) and held university degrees (86% of mothers and 76% of fathers). The sample was on average of high SES although there was within-group variation.

Procedure

Parents first reported their demographic and child's characteristics via an online survey. Each family then received a hand-delivered box containing a) 3 LENA audio-recorders, b) 3 LENA children's clothes, and c) a Parent Report of Children's Abilities (PARCA) booklet. Parents were instructed to independently audio-record for 3 days when they were mainly at home with their child, and to administer the PARCA booklet at home to their child at a convenient time. Each family received a child LENA t-shirt for their participation, and 79 families also received £50 cash, which only became available after the first families had participated due to changes in the study's funding. There was no difference in any of the variables between those families that did and those that did not receive monetary compensation.

Measures

Language.

Adult word counts. LENA audio-recorders were "worn" by the children in the front pocket of custom-made clothing. These small, lightweight devices recorded all sounds within a six-foot radius of the study child for up to 16 hours per day. The total number of words that a child heard from all adults in their environment over the 3 recording days were extracted using LENA pro software version V3.4.0 –143. Good inter-rater reliability (Cohen's k 0.65) between LENA- and human-derived adult word counts has been reported in a sample of 70 12-hr recordings (Zimmerman et al., 2009).

Lexical diversity. We selected two 5-minute audio excerpts per day between 8am and 11am, and 5 pm and 8pm that registered the highest conversational turn count in LENA (i.e., 2 x 5 minutes, across 3 days, totalling 30 minutes per family). Conversational turns refer to adult-child interactions in which one speaker initiates a conversation and the other responds within 5 seconds. We decided to use the highest conversational turn counts within the morning and evening to capture the richest adult-child interactions. Overall, 92 families had 6 audio excerpts and 15 families had 4 or 5 audio excerpts available for transcription. The audio excerpts were transcribed by professional typists using the Codes for Human Analysis of Transcripts (CHAT; MacWhinney, 2000) and proofread by two trained research assistants. Each family's transcripts (i.e., six in total) were combined and all adult speakers were assigned the same code. The combined transcripts were subjected to VOCD analysis in the Computerized Language Analysis (CLAN; MacWhinney, 2000) program, which generates D scores. D scores estimate the probability of a speaker introducing a new word into successively longer samples of speech and as such represents lexical diversity. Study child D scores were computed in the same way as adult D scores, by performing VOCD analysis on the combined transcripts.

V*ocabulary sophistication.* From the combined transcripts, described above (i.e., 30 minutes per family), we removed all words on the Dale-Chall word list, as well as their inflected forms, and all non-dictionary words, including names of family members, friends and pets. The Dale-Chall word list (Chall & Dale, 1995; Dale & Chall, 1948), lists the 3,000 most common words known by fourth graders. The remaining words in the transcripts were considered sophisticated words, and hence we computed the number of sophisticated word types (i.e., number of different sophisticated words) that were uttered by the adults within a family. To control for volubility, we divided the number of adult sophisticated word types by the total number of adult word types. Likewise, children's vocabulary sophistication was calculated as the proportion of the child's sophisticated word types from their total word types. This method has been used in previous research (Rowe, 2012; Weizman & Snow, 2001).

Children's cognitive ability. The PARCA was used to measure children's non-verbal cognitive ability such as shape awareness, reasoning and problem solving (Oliver et al., 2002; Saudino et al., 1998). The PARCA comprises two components: a parent report and a parent administered testing booklet. For the online parent report, parents responded to 28 questions such as "can your child stack seven small blocks on top of each other by him or herself?" with either yes, no, or I don't know. Parent report ratings showed good reliability (Cronbach's alpha = .72) and were therefore summed.

The PARCA booklet was administered at home by the parent, and included 9 drawing, 7 copying and 10 matching tasks. Responses were assessed independently by 2 trained research assistants according to the test scoring guidelines (Oliver et al., 2002; Saudino et al., 1998). Initial inter-rater agreement of 92.9% rose to 100% after discussion with reference to the scoring instructions. Composite scores from the drawing, copying and matching tasks, which correlated .33, .42, and .51, were z transformed and summed. The 3 tasks showed good internal consistency (Cronbach's alpha = .68).

The total PARCA has been validated against the Mental Development Index of the Bayley Scales of Infant Development-II (Bayley, 1993) and the nonverbal component of the McCarthy Scales of Children's Abilities (McCarthy, 1972) in a sample of 85 3-year-olds ($r = .54$, $p < .001$, and $r = .51$, $p < .001$ respectively; Oliver et al., 2002). A revised version of the PARCA is part of the National Institute of Clinical Excellence's (2017) guidelines for assessing child development, which supports the notion that parents can accurately report on their children's abilities (Blaggan et al., 2014; Martin et al., 2013).

Socioeconomic status. SES was indexed by 3 markers: (1) Education: Parents reported the highest educational qualification they had obtained (school leaving certificate, national vocational qualification, undergraduate degree, or postgraduate degree). (2) McArthur Scale of Subjective Social Status (Adler, Epel, Castellazzo, & Ickovics, 2000): Parents were shown a ladder with 10 rungs and the following text "think of this ladder as representing where people stand in our society. At the top of the ladder are the people who are the best off, those who have the most money, most education, and best jobs. At the bottom are the people who are the worst off, those who have the least money, least education, and worst jobs or no job.” The parents were asked to indicate which rung of the ladder best represented their own status in society. (3) Overcrowding score: The number of people living in the family home was divided by the number of rooms in the household, so that a higher value indicated less overcrowding. The 3 SES markers were *z* transformed and summed. Where data was available for both parents in a family, responses were averaged.

Statistical Analysis

Only recording hours that contained at least 1 adult word were included in our analyses to exclude times when the child was sleeping. Recording duration was regressed onto adult word counts, and standardised residuals were saved and used in the subsequent analyses. The number of excerpts transcribed (range 4 to 6 across families) was regressed onto both the adults’ and children’s lexical diversity and vocabulary sophistication measures, and standardised residuals were saved.

To evaluate if children’s age moderated the association between the adult language markers and children’s cognitive and language outcomes, we generated a series of stepwise regression models that included the relevant interaction terms (i.e., children’s age x early life language experience). We fitted an independent model for each child outcome measure (i.e., lexical diversity, vocabulary sophistication, PARCA booklet and PARCA ratings). The predictors were added to each model in the following order: First, we included child gender and family SES. Next, we added children’s age, followed by the three characteristics of adult speech (i.e., adults’ word counts, lexical diversity, and their vocabulary sophistication). We tested each interaction term in a separate model, including children’s age*adults’ word counts, children’s age*adults’ lexical diversity, and children’s age*adults’ vocabulary sophistication. To adjust for multiple comparisons, the *p* value for each model was multiplied by 12 (i.e., 4 child outcomes x 3 interaction terms). Likewise, we report the 99.6 % confidence interval for all predictors, equivalent to $p = .004$.

6.4 Results

Descriptive statistics for all study variables are displayed in Table 5.1. Children’s age significantly correlated with children's lexical diversity, the PARCA book and the parent report but not with the adult language markers (range = .43 to .66; Table 5.2). Adults’ lexical diversity correlated .40 with vocabulary sophistication, supporting the measures’ concurrent validity. However, adults’ word counts were associated neither with adults' lexical diversity nor with their vocabulary sophistication, because adults' word counts reflect input from a larger number of speakers than the other adult language measures. Children's vocabulary sophistication correlated .14 with their lexical diversity.

Table 5.1

Descriptive Statistics of all Study Variables

Variable	*M*	*SD*	Minimum	Maximum
SES index	-.02	.56	-1.69	.95
Children's age in years[a]	2.74	.55	2.03	3.99
Adults' word counts[b]	18021.70	7148.62	2953.65	44652.22
Adults' lexical diversity[c]	34.26	8.41	10.54	54.72
Adults' vocabulary sophistication[c]	0	.03	-.08	.13
Children's lexical diversity[c]	21.31	13.37	-12.49	54.42
Children's vocabulary sophistication[c]	.05	.04	-.02	.24
PARCA book – standardised[d]	0	.78	-1.82	1.62
Parent report	19.41	3.31	12	27

Note. Descriptives are based on complete data N = 107 except where indicated otherwise. PARCA = Parent Report of Children's Abilities; SES = socioeconomic status; [a] average across recording days. Variables corrected for [b] recording duration, and [c] number of available recordings. [d] N = 104.

Stepwise regression analyses predicting children's lexical diversity are displayed in Tables 5.3 and 5.4. Children's age consistently predicted children's lexical diversity, accounting for 18% to 20% of the variance across the models. However, no significant interactions between children's age and the adult language markers were observed. Tables 5.5 and 5.6 show the regression models for children's vocabulary sophistication. Adults' vocabulary sophistication predicted children's vocabulary sophistication, accounting for 28% of the variance, but like before with regard to lexical diversity, there was no interaction with children's age. For children's cognitive outcomes, Tables 5.7 and 5.8 display the regression models for the PARCA book. Both children's age and adults' word counts consistently predicted PARCA book scores, accounting for 41% and 8% of the variance respectively. Although children's age did not moderate the association between adult's word counts and PARCA book scores. For the parent report, children's age explained between 24% to 27% of the variance across the models, yet no other associations were found.

Table 5.2

Pairwise Correlations Between all Study Variables

	1	2	3	4	5	6	7	8	9
1. Child gender	-								
2. Children's age	-.17	-							
3. SES index	.02	-.06	-						
4. Adults' word counts[a]	-.13	.06	.11	-					
5. Adults' lexical diversity[b]	.06	-.11	.07	-.07	-				
6. Adults' vocabulary sophistication[b]	.13	.08	.15	.14	**.40**	-			
7. Children's lexical diversity[b]	**-.21**	**.43**	.17	.17	.19	.14	-		
8. Children's vocabulary sophistication[b]	.08	.12	.04	.06	.09	**.49**	.15	-	
9. PARCA book[c]	**-.20**	**.66**	.08	**.35**	.07	**.21**	**.48**	**.25**	-
10. Parent report	**-.26**	**.55**	.07	.13	-.09	.14	**.39**	.08	**.49**

Note. Based on complete data $N = 107$ except where indicated otherwise. PARCA = Parent Report of Children's Abilities; SES = socioeconomic status. Variables corrected for [a] recording duration, [b] number of available recordings. [c] $N = 104$. Correlations significant at $p < .05$ are shown in bold.

Table 5.3

Stepwise Regression Models 1 to 3 Predicting Children's Lexical Diversity

	Children's lexical diversity											
	Model 1				Model 2				Model 3			
	B	*SE* B	β	99.6% CI	*B*	*SE* B	β	99.6% CI	*B*	*SE* B	β	99.6% CI
Gender	-.43	.19	-.22	[-1.00, .12]	-.29	.17	-.15	[-.81, .22]	-.27	.17	-.14	[-.78, .23]
SES	.31	.17	.17	[-.19, .80]	.35	.15	.20	[-.10, .80]	.30	.15	.17	[-.14, .75]
Children's age					**.42**	**.09**	**.42**	**[.16, .68]**	**.44**	**.09**	**.44**	**[.19, .69]**
AWC[a]									.05	.04	.13	[-.05, .16]
ALD[b]									.25	.09	.25	[-.02, .52]
AVS[b]									-.03	.09	-.03	[-.31, .25]
Age*AWC[a]												
Age*ALD[b]												
Age*AVS[b]												
R^2		.06				.22				.27		
F		4.23				11.04				7.53		
p		0.20				< .001				< .001		

Note. SES = socioeconomic status; AWC = adults' word counts; ALD = adults' lexical diversity; AVS = adults' vocabulary sophistication; CI = confidence interval. Variables corrected for [a] recording duration, [b] number of available recordings. Predictors significant at $p < .004$ are shown in bold. Each models' *p* value is adjusted for 12 comparisons.

Table 5.4

Stepwise Regression Models 4 to 6 Predicting Children's Lexical Diversity

	Children's lexical diversity											
	Model 4				Model 5				Model 6			
	B	*SE* B	β	99.6% CI	*B*	*SE* B	β	99.6% CI	*B*	*SE* B	β	99.6% CI
Gender	-.28	.17	-.14	[-.79, .23]	-.28	.17	-.14	[-.79, .23]	-.28	.17	-.14	[-.79, .23]
SES	.28	.15	.16	[-.17, .72]	.31	.15	.17	[-.14, .75]	.30	.15	.17	[-.14, .75]
Children's age	**.43**	**.09**	**.43**	**[.17, .68]**	**.45**	**.09**	**.45**	**[.19, .71]**	**.44**	**.09**	**.44**	**[.18, .69]**
AWC[a]	.05	.04	.12	[-.05, .15]	.05	.04	.13	[-.05, .16]	.05	.04	.13	[-.05, .16]
ALD[b]	.25	.09	.25	[-.02, .52]	.26	.09	.26	[-.02, .53]	.25	.09	.25	[-.02, .52]
AVS[b]	-.02	.09	-.02	[-.30, .26]	-.03	.09	-.03	[-.31, .25]	-.03	.10	-.03	[-.31, .25]
Age*AWC[a]	.04	.03	.11	[-.05, .14]								
Age*ALD[b]					.05	.09	.05	[-.20, .31]				
Age*AVS[b]									.03	.07	.04	[-.17, .24]
R^2		.28				.27				.26		
F		6.74				6.47				6.44		
p		< .001				< .001				< .001		

Note. SES = socioeconomic status; AWC = adults' word counts; ALD = adults' lexical diversity; AVS = adults' vocabulary sophistication; CI = confidence interval. Variables corrected for [a] recording duration, [b] number of available recordings. Predictors significant at $p < .004$ are shown in bold. Each models' *p* value is adjusted for 12 comparisons.

Table 5.5

Stepwise Regression Models 1 to 3 Predicting Children's Vocabulary Sophistication

	Children's vocabulary sophistication											
	Model 1				Model 2				Model 3			
	B	*SE* B	β	99.6% CI	*B*	*SE* B	β	99.6% CI	*B*	*SE* B	β	99.6% CI
Gender	.16	.20	.08	[-.42, .73]	.21	.20	.10	[-.38, .79]	.06	.18	.03	[-.47, .59]
SES	.06	.17	.04	[-.45, .58]	.08	.17	.04	[-.43, .59]	-.05	.16	-.03	[-.52, .41]
Children's age					.14	.10	.14	[-.15, .44]	.07	.09	.07	[-.19, .34]
AWC[a]									-.01	.04	-.01	[-.11, .10]
ALD[b]									-.11	.10	-.11	[-.39, .17]
AVS[b]									**.53**	**.10**	**.53**	**[.24, .82]**
Age*AWC[a]												
Age*ALD[b]												
Age*AVS[b]												
R^2	-0.01				0				.21			
F	0.40				0.97				5.71			
p	8.08				4.89				< .001			

Note. SES = socioeconomic status; AWC = adults' word counts; ALD = adults' lexical diversity; AVS = adults' vocabulary sophistication; CI = confidence interval. Variables corrected for [a] recording duration, [b] number of available recordings. Predictors significant at $p < .004$ are shown in bold. Each models' *p* value is adjusted for 12 comparisons.

Table 5.6

Stepwise Regression Models 4 to 6 Predicting Children's Vocabulary Sophistication

	Children's vocabulary sophistication											
	Model 4				Model 5				Model 6			
	B	*SE* B	β	99.6% CI	*B*	*SE* B	β	99.6% CI	*B*	*SE* B	β	99.6% CI
Gender	.06	.18	.03	[-.47, .59]	.07	.18	.04	[-.46, .60]	.06	.18	.03	[-.47, .59]
SES	-.06	.16	-.03	[-.53, .41]	-.06	.16	-.03	[-.52, .40]	-.05	.16	-.03	[-.52, .41]
Children's age	.07	.09	.07	[-.20, .34]	.05	.09	.05	[-.22, .33]	.07	.09	.07	[-.19, .34]
AWC[a]	-.01	.04	-.01	[-.12, .10]	-.01	.04	-.02	[-.12, .10]	-.01	.04	-.01	[-.12, .10]
ALD[b]	-.11	.10	-.11	[-.39, .17]	-.12	.10	-.12	[-.41, .16]	-.11	.10	-.11	[-.40, .17]
AVS[b]	**.53**	**.10**	**.53**	**[.24, .82]**	**.53**	**.10**	**.53**	**[.24, .82]**	**.53**	**.10**	**.53**	**[.23, .82]**
Age*AWC[a]	.01	.03	.02	[-.09, .11]								
Age*ALD[b]					-.08	.09	-.08	[-.35, .18]				
Age*AVS[b]									.01	.07	.01	[-.21, .22]
R^2		.20				.21				.20		
F		4.86				5.02				4.85		
p		< .01				< .001				< .01		

Note. SES = socioeconomic status; AWC = adults' word counts; ALD = adults' lexical diversity; AVS = adults' vocabulary sophistication; CI = confidence interval. Variables corrected for [a] recording duration, [b] number of available recordings. Predictors significant at $p < .004$ are shown in bold. Each models' *p* value is adjusted for 12 comparisons

Table 5.7

Stepwise Regression Models 1 to 3 Predicting PARCA Book

	PARCA Book[c]											
	Model 1				Model 2				Model 3			
	B	*SE* B	β	99.6% CI	*B*	*SE* B	β	99.6% CI	*B*	*SE* B	β	99.6% CI
Gender	-.32	.15	-.20	[-.76, .13]	-.16	.12	-.10	[-.51, .18]	-.14	.11	-.09	[-.46, .17]
SES	.13	.14	.09	[-.28, .54]	.10	.11	.07	[-.21, .42]	.04	.10	.03	[-.25, .32]
Children's age					**.53**	**.06**	**.64**	**[.35, .71]**	**.52**	**.06**	**.64**	**[.36, .69]**
AWC[a]									**.09**	**.02**	**.29**	**[.03, .16]**
ALD[b]									.10	.06	.13	[-.07, .27]
AVS[b]									.07	.06	.09	[-.11, .25]
Age*AWC[a]												
Age*ALD[b]												
Age*AVS[b]												
R^2		.03				.43				.55		
F		2.56				27.41				21.60		
p		1.00				< .001				< .001		

Note. PARCA = Parent Report of Children's Abilities; SES = socioeconomic status; AWC = adults' word counts; ALD = adults' lexical diversity; AVS = adults' vocabulary sophistication; CI = confidence interval. Variables corrected for [a] recording duration, [b] number of available recordings. [c] $N = 104$. Predictors significant at $p < .004$ are shown in bold. Each models' *p* value is adjusted for 12 comparisons.

Table 5.8

Stepwise Regression Models 4 to 6 Predicting PARCA Book

	PARCA Book[c]											
	Model 4				Model 5				Model 6			
	B	*SE* B	β	99.6% CI	*B*	*SE* B	β	99.6% CI	*B*	*SE* B	β	99.6% CI
Gender	-.14	.11	-.09	[-.46, .18]	-.14	.11	-.09	[-.46, .18]	-.14	.11	-.09	[-.45, .18]
SES	.04	.10	.03	[-.25, .33]	.04	.10	.03	[-.25, .33]	.04	.10	.03	[-.25, .32]
Children's age	**.52**	**.06**	**.64**	**[.36, .69]**	**.51**	**.06**	**.63**	**[.34, .69]**	**.52**	**.06**	**.64**	**[.36, .69]**
AWC[a]	**.09**	**.02**	**.29**	**[.03, .16]**	**.09**	**.02**	**.29**	**[.03, .16]**	**.09**	**.02**	**.29**	**[.03, .16]**
ALD[b]	.10	.06	.13	[-.07, .27]	.10	.06	.13	[-.07, .27]	.10	.06	.13	[-.07, .27]
AVS[b]	.07	.06	.09	[-.11, .25]	.07	.06	.09	[-.11, .25]	.07	.06	.09	[-.11, .25]
Age*AWC[a]	-.01	.02	-.02	[-.07, .06]								
Age*ALD[b]					-.02	.54	-.03	[-.18, .14]				
Age*AVS[b]									-.04	.05	-.05	[-.17, .10]
R^2	.54				.54				.54			
F	18.35				18.39				18.53			
p	< .001				< .001				< .001			

Note. PARCA = Parent Report of Children's Abilities; SES = socioeconomic status; AWC = adults' word counts; ALD = adults' lexical diversity; AVS = adults' vocabulary sophistication; CI = confidence interval. Variables corrected for [a] recording duration, [b] number of available recordings. [c] $N = 104$. Predictors significant at $p < .004$ are shown in bold. Each models' p value is adjusted for 12 comparisons.

Table 5.9

Stepwise Regression Models 1 to 3 Predicting Parent Report

	Parent Report											
	Model 1				Model 2				Model 3			
	B	*SE* B	β	99.6% CI	*B*	*SE* B	β	99.6% CI	*B*	*SE* B	β	99.6% CI
Gender	-1.72	.62	-.26	[-3.55, .11]	-1.14	.53	-.17	[-2.72, .43]	-1.21	.55	-.18	[-2.82, .40]
SES	.47	.55	.08	[-1.16, 2.10]	.65	.47	.11	[-.74, 2.03]	.52	.48	.09	[-.89, 1.93]
Children's age					**1.73**	**.27**	**.52**	**[.94, 2.52]**	**1.65**	**.27**	**.50**	**[.84, 2.50]**
AWC[a]									.06	.11	.04	[-.27, .39]
ALD[b]									-.28	.29	-.09	[-1.14, .58]
AVS[b]									.46	.30	.14	[-.43, 1.34]
Age*AWC[a]												
Age*ALD[b]												
Age*AVS[b]												
R^2		.06				.32				.32		
F		4.15				17.65				9.36		
p		.22				< .001				< .001		

Note. SES = socioeconomic status; AWC = adults' word counts; ALD = adults' lexical diversity; AVS = adults' vocabulary sophistication; CI = confidence interval. Variables corrected for [a] recording duration, [b] number of available recordings. Predictors significant at $p < .004$ are shown in bold. Each models' *p* value is adjusted for 12 comparisons.

Table 5.10

Stepwise Regression Models 4 to 6 Predicting Parent Report

	Parent Report											
	Model 4				Model 5				Model 6			
	B	*SE* B	β	99.6% CI	*B*	*SE* B	β	99.6% CI	*B*	*SE* B	β	99.6% CI
Gender	-1.23	.54	-.19	[-2.84, .37]	-1.25	.55	-.19	[-2.86, .37]	-1.26	.54	-.19	[-2.85, .34]
SES	.44	.48	.07	[-.98, 1.86]	.53	.48	.09	[-.88, 1.94]	.52	.47	.09	[-.87, 1.91]
Children's age	**1.61**	**.27**	**.49**	**[.80, 2.42]**	**1.70**	**.28**	**.51**	**[.87, 2.53]**	**1.61**	**.27**	**.49**	**[.82, 2.42]**
AWC[a]	.05	.11	.04	[-.28, .38]	.06	.11	.05	[-.27, .40]	.07	.11	.05	[-.26, .40]
ALD[b]	-.28	.29	-.08	[-1.13, .58]	-.25	.29	-.08	[-1.12, .61]	-.26	.29	-.08	[-1.11, .60]
AVS[b]	.48	.30	.15	[-.40, 1.37]	.45	.30	.14	[-.44, 1.34]	.43	.30	.13	[-.45, 1.31]
Age*AWC[a]	.13	.10	.10	[-.17, .44]								
Age*ALD[b]					.22	.27	.07	[-.59, 1.03]				
Age*AVS[b]									.38	.22	.14	[-.25, 1.02]
R^2		.33				.32				.34		
F		8.31				8.09				8.65		
p		< .001				< .001				< .001		

Note. SES = socioeconomic status; AWC = adults' word counts; ALD = adults' lexical diversity; AVS = adults' vocabulary sophistication; CI = confidence interval. Variables corrected for [a] recording duration, [b] number of available recordings. Predictors significant at $p < .004$ are shown in bold. Each models' *p* value is adjusted for 12 comparisons.

6.5 Discussion

Using data from naturalistic home observations, we tested if children's age moderated associations between characteristics of adult speech and children's language and cognitive outcomes. In line with previous studies (e.g., Caskey et al., 2014; Hart & Risley, 1995; Weizman & Snow, 2001), we found positive associations between some characteristics of adult speech and children's language and cognitive outcomes (i.e., main effects). However, we found no support for the hypothesis that children's age moderated these associations. This finding fails to substantiate earlier findings that the quantity of adult speech influences children's early language development but later, the diversity and sophistication of the language input become more important (Rowe, 2012).

Associations between Characteristics of Adult Speech and Children's Outcomes

We found that the quantity of adult speech accounted for 8% of the variance in children's PARCA booklet scores, suggesting that children who were exposed to a greater amount of language had better cognitive ability. It is plausible that the exposure to a large number of words provides more learning opportunities for children that help enhance their general cognitive development. However, the quantity of adult speech was not associated with children's cognitive ability when it was rated by parents. It is possible that parents may be less accurate in judging their child's cognitive ability, compared to when children actually demonstrate their skills in a test.

The lexical diversity of adult speech was not associated with children's cognitive or language outcomes. Because we applied a conservative adjustment for multiple comparisons to our regression models, the association between adults' and children's lexical diversity was non-significant. Without this adjustment, adults' lexical diversity was a significant predictor at $p < .01$ of children's lexical diversity, explaining 6% of the variance. This effect size is comparable to that reported by Rowe (2012), who did not adjust for multiple comparisons in her analyses.

We found that adults' vocabulary sophistication predicted children's vocabulary sophistication. It is possible that this association is due to discourse effects, as both the adults' and children's vocabulary sophistication measures were derived from the same audio excerpts. However, it is also plausible that children exposed to a large variety of sophisticated words have more opportunity to learn these words, which they can then embed into their own productive vocabulary (Weizman & Snow, 2001).

Adults' lexical diversity moderately correlated with their vocabulary sophistication, which suggests that these are distinct, yet inter-related language markers. By comparison, the quantity of adult speech was not related to adults' lexical diversity or to their vocabulary sophistication. This may be because the quantity of adult speech represents three days of interactions between a larger number of speakers than the diversity and sophistication measures. In other words, the quantity of adult speech reflects more broadly children's daily language environments, rather than the times of heightened language interactions.

We found no significant association between the diversity and sophistication of children's spoken language. This finding corroborates the notion that these two measures are tapping into distinct aspects of vocabulary richness (Malvern, Richards, Chipere, & Durán, 2004), at least in young children.

Children's Age as a Moderator

Previous studies suggested that children's age moderates the association between characteristics of adult speech (i.e., the lexical diversity and vocabulary sophistication) and children's own language (Jones, & Rowland, 2017; Pan et al., 2005; Rowe, 2012). Once children have a basic vocabulary, the exposure to a larger variety of different and rare words increases the opportunity for word-learning. Although, we found no evidence for a moderation effect, children's age added to our models' prediction by 14%, 40% and 27% for children's lexical diversity, their PARCA booklet performance and their parents' ratings of cognitive development, respectively. By comparison, children's age did not add to the model for child vocabulary sophistication.

Our study differed from previous studies on three key attributes: first, we assessed all speech heard by the child, whereas the previous studies measured maternal speech directed to the child (Jones, & Rowland, 2017; Pan et al., 2005; Rowe, 2012). Because our study used unobtrusive audio-recordings with excerpts selected, unknown to the families, for the highest conversational interactions between adults and children, it is more representative of natural language environments than solely focusing on maternal-child interactions. Second, we computed D-scores as our measure of children's lexical diversity akin to Jones and Rowland (2017), yet Pan et al. (2005) used word types, which are influenced by the number of words in the sample of speech and thus it is not an independent measure. Opting for another alternative assessment, Rowe (2012) assessed children's receptive vocabulary via a standardised test, which measures words that children know or understand. Receptive vocabulary is contrasted with expressive vocabulary, which refers to words that children can actually say. This differentiation reflects that in language development, children may understand a word but cannot (yet) vocalise it. Naturalistic observations of expressive vocabulary, like in our study, are reliant on the child spontaneously producing the words, which may not happen during a recording session even though the child can vocalise the word.

Third, we assessed concurrent interactions between adults and children. By comparison, the earlier studies were longitudinal, with the times between assessments varying from 5 to 22 months. Because our study was cross-sectional the child age variable also encompassed intra-individual variation: children differed not only on age but also on other unexamined factors. We attempted to address this issue by controlling for SES and gender in our analysis but nevertheless, we were unable to control for all potential confounds.

Only Pan et al. (2005) formally tested the interaction between children's age and characteristics of adult speech on children's language. Both Jones and Rowland (2017) and Rowe (2012) compared associations between earlier input and later child language, whilst controlling for children's earlier vocabulary in their analysis. Because we were unable to adjust for children's previous language ability, we would expect that the associations between language input and children's language outcomes in our study are higher than those previously reported, as the variance explained by earlier ability would be subsumed within our child language outcome variables.

Although we attempted to address some of the limitations of previous research in this area, we did not observe an interaction effect between children's age and characteristics of adult speech in the prediction of children's cognitive and language skills. We suggest that future work in this area would benefit from careful methodological considerations. Digital technologies enable collecting naturalistic home observations over long durations (i.e., days) that are free from observer biases, resulting in rich 'big' data. Moreover, digital technologies can better afford collecting such 'big' data from large, well-powered samples than is possible with trained researchers that conduct multiple home visits over time.

Limitations

Our study has many strengths but also several limitations. First, because our study design was cross-sectional, we did not assess children's responses to language input over time or their individual growth trajectories. Our study design also implies that the observed age-related differences may be confounded with children’s differences in cognitive and language abilities. Second, we relied on 30 minutes of observations for our assessment of lexical diversity and vocabulary sophistication, which may be too short to get an accurate representation of children’s language abilities, although this observation period is comparable to previous studies (Pan et al., 2005). Third, we derived adults’ and children’s lexical diversity and vocabulary sophistication measures from the same transcripts and thus, they may be influenced by discourse effects that make their observations dependent on one another. Fourth, Tabachnick and Fidell (2014) suggest using a sample size of 104 plus the number of predictors, to test the influence of the predictors on a dependent variable in a regression model when there is a medium effect size. For our full regression models, our sample size of 107 falls slightly short of their recommendation (i.e., 104 + 7 = 111). Nevertheless, our sample size is comparable to other research in this field.

6.6 Conclusion

Using unobtrusive audio recordings, we show that characteristics of adult speech are associated with children’s language and cognitive skills. Our findings suggest that these associations do not vary meaningfully across children’s age. We encourage future studies in this area to adopt longitudinal designs and collect rich naturalistic observations to explore the importance of adult speech for children’s cognitive and language outcomes throughout their developmental stages.

6.7 References

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7 Discussion

This thesis sought to test associations between aspects of the home environment and children's linguistic, cognitive and behavioural outcomes using extensive naturalistic observations. In addition, this thesis also investigated whether these associations were moderated by children's age. In paper 1, I found that the quantity of adult words that children heard was related to their cognitive ability but not to their linguistic or behavioural outcomes. By comparison, the diversity of language input predicted children's lexical diversity, and parenting was related to children's behavioural outcomes. The key finding from paper 2 was that parental literacy behaviours were associated with children's cognitive ability, independent of the adult speech that children heard in the family home. Lastly, paper 3 revealed that associations between characteristics of adult speech and children's outcomes were not differentiated by children's age in the current sample. The findings are discussed in detail below, noting strengths limitations and future directions.

7.1 Language Input and Children's Language Outcomes

The quantity of language input that children were exposed to, was not associated with their language outcomes. A possible reason for this finding is that the measure used to estimate the quantity of adult speech (i.e., adult word counts) included both overheard and child-directed speech. However, previous studies have shown that only child-directed speech is associated with children's language (Weisleder & Fernald, 2013). Some authors suggest that this is because young children do not possess the attentional demands necessary to attend to overheard speech and subsequently extract vital linguistic information (Golinkoff, Hoff, Rowe, Tamis-LeMonda, & Hirsh-Pasek, 2018). In addition, child-directed speech is often different in content, tempo and prosody compared with adult-directed speech, with the former aiding language acquisition (Golinkoff et al., 2018). Because the quantity of language input measure was not differentiated into overheard and child-directed speech, associations were likely blurred in this study.

In the current thesis, audio excerpts that contained the most conversational turns in the morning and afternoon of each day were extracted for further analysis. These excerpts comprised heightened adult-child language interactions and thus are more likely to reflect child-directed speech than the quantity measure. Language markers derived from these excerpts (i.e., adults' lexical diversity and vocabulary sophistication) were associated with children's own lexical diversity and vocabulary sophistication, suggesting that heightened language interactions are necessary for language acquisition (Huttenlocher, Waterfall, Vasilyeva, Vevea, & Hedges, 2010; Pan, Rowe, Singer, & Snow, 2005).

Perhaps the LENA adult word count measure is not sensitive enough to detect the social interactions that are imperative for language learning. Romeo et al. (2018) found a relation between the number of conversational turns, which measure the reciprocal nature of adult-child conversations, and neural activation in Broca's area, a brain region associated with language. However, they were unable to find a relation between the quantity of adult speech and children's neural response. Therefore, it would be interesting to investigate LENA derived conversational turn counts in future studies using my sample, to assess if it is a prominent predictor of child outcomes. This is plausible considering that social learning and usage-based theories of language acquisition propose that social interactions are the foundations of language learning (Bandura, 1971; Tomasello, 2003).

7.2 Language Input and Children's Cognitive Outcomes

The findings from this thesis support the notion that children who hear more linguistic input tend to have better cognitive skills than children who hear less (Goldwin-Meadow et al., 2014). The association between the number of adult words and children's cognitive ability was only significant when cognitive ability was assessed by the PARCA booklet and not by the parent report of children's abilities. This is surprising because previous studies reported that the parent report component of the PARCA was more strongly associated with the McCarthy Scales of Children's Abilities (McCarthy, 1972) than the PARCA booklet (Oliver et al., 2002). In addition, the parent report was also more highly associated with the Mental Development Index (MDI) of the Bayley Scales of Infant Development-II (Bayley, 1993) than the PARCA booklet (Saudino et al., 1998). Notwithstanding, no previous study has assessed the association between adult word counts and the two components of the PARCA. Saudino et al. (1998) report that each component of the PARCA contributes unique prediction to the MDI which suggests that each component is capturing slightly different aspects of cognitive ability. Perhaps the quantity of language input supports one area of cognitive development more strongly than another.

Various mechanisms that underpin the association between language input and children's cognitive abilities have been proposed, such as associative learning (Jones & Macken, 2018), statistical learning (Saffran, Senghas, & Trueswell, 2001), and practicing cognitive skills such as working memory (Sheridan, Sarsour, Jutte, D'Esposito, & Boyce, 2012).

Associative learning is a process by which new knowledge is gained based on perceived associations between two or more stimuli or events (Jones et al., 2020). It has been suggested that language exposure enhances associative domain-general learning, which is a cognitive skill that can be applied to both verbal and non-verbal tasks (Jones & Macken, 2018). Basic associative learning operates on the amount of linguistic experience that a child encounters, which then predicts performance on cognitive tests that assess higher order cognitive skills (Jones & Macken, 2018). Another study using computational modelling reported that the amount of language exposure is imperative for the formation of semantic categories (i.e., placing an object into a category based on its properties; Borovsky & Elman, 2006). This cognitive ability to categorise objects and form mental representations could be extrapolated to other tasks, such as the matching task in the PARCA booklet which asks the child to identify which picture matches the target picture, based on a distinguishing property.

Another mechanism that has been proposed is statistical learning: 8 month old infants use the statistical relationship between neighbouring speech sounds to segment words from the fluent speech that they hear (Saffran, Aslin, & Newport, 1996). This statistical learning can also be applied to non-verbal domains, such as music (Saffran et al., 2001), and as such, more exposure to speech may train these cognitive abilities that are related to language but are also recruited in other tasks.

It has been suggested that parental language use directly affects child cognition. From 22 months, infants can extract information given verbally to select the correct object solely by the information contained within speech, and therefore update their mental representation of that object (Ganea, Shutts, Spelke, & Deloache, 2007). This representational thinking is the foundation for higher order cognitive skills (Daneri et al., 2019). Children exposed to a greater quantity of adult speech have more opportunities to form mental constructs on which they can then reflect upon which supports the development of executive functioning (Daneri et al., 2019).

Children, aged 8 to 12 years, with greater exposure to complex language in the family home (i.e., the number of word roots, bound morphemes and conjunctions) had better task accuracy on a non-verbal stimulus-response learning task and also decreased brain activation in the prefrontal cortex suggesting they required less cognitive resources to complete the task (Sheridan et al., 2012). Therefore, the language environment may affect the development of executive functions by giving children the opportunities to practice these functions. For example, sentences which contain a conjunction may require a child to hold the start of the sentence in mind before hearing the ending and thus draw upon working memory capacity (Sheridan et al., 2012). With repeated exposure, the child's working memory is constantly being tested and developed.

The content of parental language input has also been related to children's acquisition of knowledge and thinking skills, for example, children who have learned the word *like* are able to form abstract similarity relations, whereas their deaf counterparts are not (Ozcaliskan, Goldin-meadow, Gentner, & Mylander, 2009). Likewise, children exposed to a larger quantity of adult speech related to numbers have better knowledge of numbers than children with less exposure to these number words (Levine, Suriyakham, Rowe, Huttenlocher, & Gunderson, 2010).

In sum, I speculate that the mechanisms which underpin the association between language input and children's cognitive ability are likely to involve both associative and statistical learning, and the enhanced opportunities to practice the domain-general cognitive skills that communication requires which are then extrapolated to other cognitive tasks.

7.3 Parenting and Children's Behavioural Outcomes

The finding that children's externalising behaviours were inversely associated with positive parenting supports previous research (Gulenc, Butler, Sarkadi, & Hiscock, 2018). It is plausible that positive parenting provides the child with a model of appropriate social interactions, which the child can imitate, leading to lower occurrences of restless and attention-deficit behaviours (Unternaehrer et al., 2019). In addition, positive parenting such as encouraging different forms of self-expression may, through the process of positive reinforcement, discourage undesirable behaviours such as disobedience or aggression from being exhibited by the child (Bandura, 1971). Furthermore, it is likely that transactional processes are also somewhat responsible for this association, for example, a child that displays less irritable and disobedient behaviours is more likely to illicit positive parenting from their caregiver (Avinun & Knafo, 2014; Unternaehrer et al., 2019). Another possible explanation for this finding is that parents, who are responsive and encouraging, provide a secure attachment for their child and hence less behavioural problems will develop (Bowlby, 1973; Turner, 2005).

In contrast, a child with an insecure attachment to its parent/caregiver may develop anxiety, which aligns with the finding from paper 1 that critical parenting was associated with children's internalising behaviours (Bowlby, 1973; Turner, 2005). Although the regression model in the current sample did not reach significance, associations between parental critical behaviours and 3 year old children's internalising behaviours have been reported elsewhere (Gulenc et al., 2018).

7.4 Assessment Issues

The current thesis assessed early life home environments and children's outcomes using naturalistic observations, parent reports and a cognitive ability test. I will review 4 methods typically used to assess children's home environments and their outcomes: 1) direct observations (i.e., where the observer visits the family home), 2) naturalistic observations, 3) parent reports, and 4) standardised tests. These methods can be used to assess both adults and children. Because my focus is on the home environment, lab-based observation methods will not be discussed.

Direct observations of the home environment involve researchers being present during the assessment (e.g., to operate video or audio equipment). Observing interactions between individuals allows for a more objective assessment of their behaviours than relying on parent reports (Margolin et al., 1998). In addition, direct observations are often recorded which allows the observation to be assessed at a later date and double coded which increases reliability. Despite their benefits, direct observations also have limitations. For example, the presence of a researcher may induce observer reactivity or the Hawthorne effect whereby participants alter their behaviour in response to being observed (Dudley-Marling & Lucas, 2009). Although some authors suggests that observer reactivity effects are minimal, there are not systematic differences across families and therefore observer reactivity does impose extra error variance that is best to avoid (see Gardner's (2000) review). Another important limitation of direct observations is the considerable costs involved with having researchers visit family homes. Therefore, previous studies using this assessment method often rely on small sample sizes and short observations which reduces power (Huttenlocher, Vasilyeva, Waterfall, Vevea, & Hedges, 2007; Rowe, 2008, 2012).

Naturalistic observations, in which the participants are unaware or forget about being observed, eliminate observer reactivity and thus maintain high ecological validity. This ensures that observations are valid and document real-life behaviours. In addition, naturalistic observations enable quantitative measurement of development in real-time. Furthermore, because a researcher doesn't need to be present, studies that employ digital technologies can conduct naturalistic observations on a larger scale, with greater sample sizes and durations of observations than is possible with direct observations. Nevertheless, naturalistic observations have several limitations. For one, they lack internal validity because they aim to capture real-life behaviours without imposing artificial conditions or restrictions. Therefore, particular behaviours may not be displayed during an observation despite them being part of an individual's repertoire. To account for this issue, naturalistic methods afford lengthy observations which increases the chance of particular behaviours arising spontaneously. It has also been suggested that structured tasks can be designed to increase "the consistency of sampling between individuals and the likelihood of certain behaviours arising" (Aspland & Gardner, 2003, p. 137). However, this would introduce an artificial element to the observation and thus negate the purpose of using a naturalistic method. In addition, there are still no guarantees that the behaviour of interest will emerge, even when using structured tasks. Another limitation of naturalistic observations is that they tend to have more noise in the data than direct observations because they occur in unstructured conditions for extensive time periods.

Another method typically used in developmental science is parent reports, by which parents report on their own or their child's behaviour. Considering that parents have intricate knowledge of their child, they can comment on behaviours that would occur outside an observation window and over a longer period of time, perhaps giving a truer representation of a child's ability. However, parent reports are limited by social desirability biases, mood and retrospective recall (Unternaehrer et al., 2019). It is also important to consider the informant in parent reports (i.e., the mother or father). Discrepancies between mother and father reports of their child's behaviour can be explained in part by the parent-child relationship (Treutler & Epkins, 2003). For example, mothers spending more time with the child compared with fathers accounted for the increased reporting of child internalising behaviours by mothers. In addition, mothers and fathers psychological symptoms contributed significantly to the discrepancies between their reports of their child's internalising and externalising behaviours (Treutler & Epkins, 2003).

A recent meta-analysis of 36 papers reported that observations of parenting behaviours only correlated .17 with parents' report of their own behaviour (Hendriks, Van der Giessen, Stams, & Overbeek, 2018). Neither the location of the observation (i.e., home or lab), nor when the observations were assessed (i.e., at the time of the interaction or later coded from videotapes) moderated this association. The authors do not report if a researcher or parent operated the recording equipment during the observation. Moreover, previous research suggests that parenting measures derived from both parental report and direct observations each contribute a unique prediction to children's outcomes (Oliver & Pike, 2019), suggesting that both methods have added value.

In addition to observations and parent reports, standardised tests are often used to assess children's home environments and their outcomes. A standardised test is an assessment instrument whose validity and reliability has been established through empirical investigation. In addition, standardised tests have clearly defined norms that allow for comparisons between an individual's score and a large sample which is representative of the population that the test was designed to assess. Standardised tests can be completed by children, parents or researchers.

The Home Observation for Measurement of the Environment (HOME) is a standardised test that measures the quantity and quality of stimulation and support in a child's home environment (Bradley & Caldwell, 1977). Standardised tests which assess language in children aged 2 to 4 years, include the British Picture Vocabulary Scale (BPVS-II: Dunn, Dunn, Whetton, & Burley, 1997) and the Reynell Developmental Language Scale (Edwards, Letts, & Sinka, 2011). Standardised tests of young children's language abilities are particularly important because they are norm-referenced and can therefore identify children with language delay. However, the test may only measure a facet of language and therefore some children may perform within the normal range on one test but not another, suggesting that multiple tests alongside careful observations in different contexts are necessary for a complete view of children's language abilities (Dockrell, 2001). In addition, standardised tests are commonly administered by a researcher and therefore are costly to conduct on a large scale.

Standardised tests of young children's behaviour are also prevalent in the developmental literature. The most widely used measures include the Child Behaviour Checklist (1.5–5 years; Achenbach & Rescorla, 2000), and the Strengths and Difficulties Questionnaire (SDQ; Goodman, 1997). Because standardised measures of child behaviour are widely used in the literature they allow for comparisons between studies. However, they often rely on the researcher asking the parent to report on their child's behaviour and therefore are subject to the same issues regarding parent reports described above, such as parent's psychological state influencing their assessment of their child.

In summary, there are a wide range of assessment methods that researchers can employ to study home environments and child outcomes such as direct observations, naturalistic observations, parent reports, or standardised tests.

7.4.1 Assessing Children's Home Environments and Their Outcomes in the Current Thesis

All the methods outlined above have their strengths and limitations. The current thesis opted to use naturalistic observations to assess adults' and children's language and behaviour. To assess parental literacy behaviours and children's cognitive outcomes, parent reports were used. In addition, a cognitive ability test was employed to measure children's non-verbal cognitive ability.

Language and Behaviour

The decision to employ naturalistic observations of language and behaviour was to document typical family functioning with minimal biases. In addition, naturalistic observations of parent and child behaviour are rare in the literature and allowed the testing of a novel method of data collection. Prior to my data collection, LENA had not been used in a British population and therefore I was testing if this technology was acceptable for British families, and feasible for assessing language and behaviour. Furthermore, using LENA digital audio recorders enabled a large sample of families to be observed over extensive durations which increased power and the likelihood to detect meaningful associations.

In order to assess real-life spontaneous interactions in the family home, it was essential that the participants were blinded to the segments of time in which their language and behaviours were observed (i.e., when the audio extracts would be extracted for further analyses). This time-sampling approach ensures high ecological validity of observations, yet it still suffers from the possibility that a behaviour may not spontaneously occur within the selected time period. To address this issue, future research could sample more time periods from these inconspicuous recordings and thus increase representativeness, but this must be balanced with respecting the privacy of the families and considered within the limits of researcher resources.

A more comprehensive approach that also includes parent reports and standardised tests of children's language and behaviour is likely to explain more of the variance in child outcomes than naturalistic observations alone. It is a limitation of this work that no standardised test of children's language or behaviour was administered. Future studies would benefit from systematically comparing naturalistic observations with standardised measures.

Literacy Behaviours and Cognitive Ability

In the current thesis, parents reported on their own literacy behaviours and their children's cognitive abilities. The rationale for using parental reports for these measures was because the main focus of this thesis was on language and therefore it was outside the scope of this thesis to also assess parental literacy behaviours and children's cognitive abilities using naturalistic observations. In addition, the literacy measure encompassed literacy beliefs which are not directly observable and as such required parents to report on their own beliefs.

The Parent's Report of Children's Abilities included a test in addition to a parent report. The rationale for choosing the PARCA to measure children's non-verbal cognitive ability was because it is a well-established psychometric test that is suitable for parent administration.

Assessing Parenting via Audio Recordings

To assess parenting, a novel coding scheme was used to rate parents' behaviours from audio excerpts. Two raters were trained to apply the coding scheme and were given the opportunity to ask any questions that arose during the entire rating process. Nevertheless, they differed somewhat in their assessments of parents' behaviours. It is likely that human error and biases reduced reliability between raters (Aspland & Gardner, 2003).

Inter-rater reliability. The parenting behaviours which showed the least agreement by raters (i.e., the lowest percentage in identical codes) were, *expression* (17.87%), *responsive* (33.54%), *reasons* (57.37%), and *novelty* (57.68%). All of these items, with the exception of *reasons*, loaded onto the positive parenting dimension. By comparison, the most agreement between raters was found for the following behaviours, *physical* (100 %), *threatens* (97.49 %), *shout* (97.18%) and *criticises* (96.55%). Considering there were zero incidences of physical behaviour (e.g., hitting), it is not surprising that the raters were in complete agreement. Likewise, all critical parenting behaviours were less frequent and had lower variance than the positive parenting behaviours.

The low inter-rater reliabilities for the positive parenting items are of particular concern and suggest that the current method may not be suitable to reliably quantify parenting. There are three points to consider regarding these low inter-rater reliabilities, including 1) method, 2) measures, and 3) analysis strategy. First, it is possible that parenting cannot be quantified via 5-minute excerpts of audio recordings and that longer observations are needed to accurately assess parenting via audio recordings. In addition, it is possible that audio data per se are not rich enough to discern adult behaviours, because they lack visual information, such as facial expressions and body language, which provide useful cues for interpreting a person's behaviour. These two issues may affect particularly the assessment of positive parenting, including responsiveness and encouraging expression in children, that are difficult to identify from short observation periods or conclude about based on specific parenting behaviours.

The second point to consider regarding the low inter-rater reliabilities for positive parenting is the measure used to assess audible parenting behaviours. This novel measure was derived from the Parenting Styles and Dimensions Questionnaire (PSDQ; Robinson, Mandleco, Olsen, & Hart, 1995), which was originally designed as a parent report comprising 62 items. Reducing this questionnaire to just 8 items and including a further 2 items from the "opportunities for variety in daily stimulation" subscale of The Home Observation for Measurement of the Environment (HOME, Caldwell & Bradley, 1984) may not have resulted in a psychometric instrument sufficient to assess parenting.
Lastly, the analysis strategy is important to consider when dealing with low inter-rater reliabilities. The strategy employed in this thesis was to include all parenting items in the factor analysis because the average inter-rater reliability of 73% across all items was assumed to be sufficient. However, ideally the inter-rater reliability for each item should have been 70% or above to be considered adequate (Multon & Coleman, 2018; Stemler & Tsai, 2008). Given the issues with inter-rater reliabilities of parenting behaviours, further work is required to test if audio recordings can be successfully used to assess parenting. Recommendations for future studies are twofold: first, the optimal duration of audio excerpts that are required for the accurate assessment of parenting behaviours need to be investigated. Second, a range of parent report and observational measures may need to be explored to develop instruments that allow for the accurate assessment of audible behaviours. Further work will be required to determine how best to develop a coding scheme for these audible observational measures, a coding scheme that improves the agreement of parenting behaviours across raters, so that each item will have an inter-rater reliability of 70% or above.

There are several possible explanations for why critical parenting showed greater inter-rater reliability than positive parenting behaviours. First, the raters may be more attuned to noticing negative behaviours because they may be perceived as a threat. Such negativity biases are commonly found in psychology, and may be adaptive for survival by making the individual more alert and vigilant when faced with negative stimuli (Baumeister, Bratslavsky, Finkenauer, & Vohs, 2001; Norris, 2019). Another possible explanation for the discrepancy in inter-rater reliabilities between positive and critical parenting is each raters subjective notions about what comprises each behaviour. For example, *shouting* is more obvious to discern than *expression* which requires the listener to interpret the content of the speech rather than just its amplitude.

In hindsight, perhaps the descriptions of each parenting behaviour that the raters used to base their assessments on were not detailed enough and left too much room for interpretation. Future research may benefit from a more precise coding scheme to reduced ambiguity between raters. For example, by giving specific examples of actions that could be categorised for each behaviour, such as, a parent suggesting their child does some drawing is an example of expression. Although this information was given verbally to the raters, a paper version of a checklist of actions may have made each rater more attuned to seeking out that behaviour in the audio excerpts and would therefore increase consistency between their codes. Another suggestion for improving inter-rater reliability would be to embed more quality assurance into the process, and to repeat training at regular intervals to ensure each rater agrees on which actions demonstrate certain behaviours.

Rationale for combining mothers' and fathers' parenting codes. Mothers' and fathers' parenting codes showed low to moderate correlations suggesting that parenting within families differs as a function of the parent. However, for only 39 families parenting codes were available for both parents, resulting in a small sample with insufficient power to analyse parenting separately for fathers and mothers. In addition, I sought to assess early life experiences as comprehensively as possible, opting for holistic assessment approaches where possible. For example, children's early life language experiences were captured in terms of adult words spoken and adults' lexical diversity; both constructs were not differentiated into fathers and mothers. I employed the same approach to parenting; by combining mothers' and fathers' parenting codes, a comprehensive measure of children's early life parenting emerges. Future research in larger samples will be required to differentiate the influence of mothers' parenting from that of fathers on child development.

Why positive parenting showed stronger associations than critical parenting. In the regression models for child behaviour (Table 1.4), positive parenting was more strongly related to child externalising behaviour than critical parenting was (β = -.25, 95% CI = -.45, -.04, and β = .18, 95% CI = -.02, .37, respectively). However, for the internalising child behaviour model, the opposite effect was found, critical parenting showed a stronger relation to child behaviour than positive parenting did (β = .30, 95% CI = .10, .50, and β = .01, 95% CI = -.20, .22, respectively), although this model did not reach significance.

In contrast to my findings, previous research suggests that critical parenting is a stronger predictor of children's externalising behaviours than positive parenting (Gulenc et al., 2018; Oliver & Pike, 2019). In my description of these studies, I refer to critical parenting which is defined as negative attitudes and feedback to the child, expressions of disapproval and even threatening behaviour (Sher-Censor, Shulman, & Cohen, 2018). Therefore, critical parenting is a broad term akin to the terms negative or harsh parenting used in other studies.

A recent study observed 119 mothers completing the *Etch-a-Sketch Online* (ESO) task with their children aged 5 years (*M* = 5.51 years, *SD* = 4.92 months; Oliver & Pike, 2019). The ESO task involved parents and children co-operating to draw a picture on a computer, whilst being remotely video recorded via the computer's webcam. Observations were coded for verbal and non-verbal indicators of positive and critical parenting. Positive parenting was assessed by the frequency of positive affect (e.g., interest, affection), and positive control (e.g., praise, use of open-ended questions). Critical parenting was composed of negative affect (e.g. frowning, rejection), and negative control (e.g., criticising, shaming). Six months after the ESO task, when the children were on average aged 6.04 years (*SD* = 5.52 months), mothers reported on their child's disruptive behaviour using the Eyberg Child Behavior Inventory (Eyberg & Pincus, 1999). In addition, the mothers also reported on their own positive and critical parenting at time 2. ESO observed critical parenting predicted more of the variance in children's externalising behaviour than ESO observed positive parenting. Likewise, maternal reports of critical parenting showed stronger associations with children's externalising behaviour compared with maternal reports of positive parenting.

In an earlier study, 669 fathers reported on their own parenting and their 3-year olds behaviour (Gulenc et al., 2018). Critical parenting was measured from 10 items on the Parent Behavior Checklist (Fox, 1994), for example, "I yell at my child for whining". Likewise, positive parenting was measured from 10 items on this checklist (e.g., "I praise my child for learning new things"). Results indicated that critical parenting was more strongly associated with children's externalising behaviours compared to positive parenting.

The discrepancy between my results and the aforementioned studies is likely to arise from two underlying causes, first, the low inter-rater reliabilities of the positive parenting items, and second, the low variance in critical parenting. Because critical parenting was difficult to assess via audio recordings it resulted in no predictive validity and therefore more precise coding is required to accurately assess parenting.

7.5 Effects of Parental Literacy Behaviours and Beliefs on Children's Outcomes

The improvements in child cognition and language that come about from parental literacy behaviours, such as shared book reading, are often framed within a Vygotskian approach (Vygotsky, 1978). For example, scaffolding used during shared book reading is thought to aid child development: if parents attend to their child's cues, pitch their responses at an appropriate developmental level and provide further stimulation to gradually challenge their child, this process reinforces knowledge and understanding whilst encouraging learning.

7.5.1 Children's Language

In paper 2 no significant associations were found between parents' literacy behaviours and beliefs and children's language outcomes. This is in contrast to previous research which found that shared book reading was associated with greater vocabulary, syntax, comprehension monitoring and narrative comprehension (Grolig, Cohrdes, Tiffin-Richards, & Schroeder, 2019; Head Zauche, Thul, Darcy Mahoney, & Stapel-Wax, 2016). An earlier study which incorporated story-telling and singing nursery rhymes alongside shared book reading in their assessment of literacy behaviours, reported correlations of .21 and .14 between parental literacy behaviours and children's productive language at child ages 24 and 36 months respectively (Rodriguez, et al., 2009).

It has been proposed that shared book reading elicits adult speech that is more conducive to language learning. For example, adult speech is more child-directed, and both lexically and syntactically diverse during shared book reading compared to play-based activities (Huttenlocher, Vasilyeva, Cymerman, & Levine, 2002; Noble, Cameron Faulkner, & Lieven, 2018). Specifically, children's language development is enhanced during shared book reading when the parent 1) asks wh-- questions and open-ended questions, 2) repeats, recasts and expands their child's speech, and 3) provides praise and corrective feedback dependent on the child's responses (Flack, Field, & Horst, 2018; Whitehurst et al., 1988). Therefore, active responding by the child is pivotal for their own language development (Whitehurst et al., 1988).

Possible reasons for the discrepancy in findings between my study and previous ones are threefold: first, the majority of previous studies only focused on shared book reading, whereas my assessment of parental literacy behaviours and beliefs was a more comprehensive view of the home literacy environment. Second, parental literacy behaviours and beliefs may be more predictive of children's receptive rather than expressive vocabulary, although previous studies contradict one another on this point (Deckner, Adamson, & Bakeman, 2006; Quach et al., 2018). Third, it is possible that parental literacy behaviours and beliefs could be more strongly related to children's syntactic ability compared to their vocabulary skills, however syntax was not assessed in this study.

In sum, the variety of assessment measures used in previous studies to index parental literacy behaviours and children's language outcomes make direct comparisons difficult. Therefore, future studies should attempt to encompass comprehensive assessments of both parental literacy behaviours and also children's language.

7.5.2 Children's Cognitive Abilities

In paper 2, parental literacy behaviours and beliefs predicted children's cognitive ability independent of the adult speech that children were exposed to in the family home. The notion that parental literacy behaviours can enhance children's cognitive abilities has been reported elsewhere (Rodriguez, et al., 2009; Saracho, 2017; Shahaeian et al., 2018). For example, 1046 mother-child dyads were assessed at child ages 24 and 36 months (Rodriguez, et al., 2009). At both time points, the mothers reported on their literacy behaviours including shared book reading, story-telling, and singing nursery rhymes. To measure children's cognitive ability, trained researchers administered the Bayley Mental Development Index of the Bayley Scales of Infant Development (BSID-II; Bayley,1993) which assesses memory, problem solving, early number concepts, generalisation skills, classification abilities, vocalisations and language, and social skills. Maternal literacy behaviours accounted for 18% and 14% of the variance in children's cognitive ability at 24 and 36 months, respectively (Rodriguez, et al., 2009). The authors suggested that a plausible reason for these associations is that literacy behaviours such as shared book reading exposes children to general knowledge and concepts rarely encountered in their normal daily lives.

In a later study with a sample of 4,768 children, the frequency of shared book reading was assessed in toddlerhood (ages 2 to 3 years; Shahaeian et al., 2018). At follow up, one year later (i.e., when the children were 4 to 6 years of age), the children were tested on cognitive processes underlying early literacy and numeracy skills. The test encompassed 11 items that included identifying and copying geometric shapes, and writing symbols such as letters, words and numbers. Exposure to literacy behaviours in toddlerhood predicted cognitive ability 1 year later ($\beta = .06$, $p < .001$). When parents engage their children in discussions during shared reading this promotes problem solving skills and in turn enhances their general cognitive development (Shahaeian et al., 2018).

There are several possible mechanisms that may explain the association between parental literacy behaviours and beliefs, and children's cognitive ability. First, literacy promoting behaviours such as storytelling and shared book reading, expose children to novel concepts and thus contribute to their general knowledge. Second, literacy behaviours that involve stories are often accompanied by a problem which needs to be solved within the narrative of the story. Therefore, when parents and children engage in literacy activities such as shared book reading, this fosters the opportunity for adult-child conversations that require the child to solve problems and hence train this cognitive skill. A third plausible explanation is shared genes between parents and children, so that more intelligent parents may engage in more literacy promoting behaviours, however their offspring will also be inherently brighter.

In conclusion, parental literacy behaviours expose children to concepts and thought-provoking questions which enhances their specific knowledge (e.g., about numbers and shapes), and their general cognitive abilities such as memory and problem solving. This effect may be partly accounted for by genetic effects.

7.6 Child Age as a Moderator of the Language Environment

In paper 3, I found no evidence to support the notion that child age moderates associations between characteristics of adult speech and children's outcomes. This suggests that for children, aged 2 to 4, the language input that they experience does not have a greater or lesser influence depending on their age. This finding contradicts previous studies that reported that the quantity of adult speech is most important in the initial stage of language acquisition, but once children have built up a vocabulary base the diversity and sophistication of adult speech have a stronger influence on children's language abilities (Jones & Rowland, 2017; Pan et al., 2005; Rowe, 2012).

The most notable differences between my study and previous work in this area is that my study relied on cross sectional data, whereas previous studies used longitudinal designs. Therefore, I was unable to track individual growth trajectories or control for children's previous language ability. Due to my cross-sectional study design, the child age variable also encompassed intra-individual variation: children differed not only on age but also on other factors such as language ability. Because children acquire language at different rates, it may be that age is not the moderator between early life experiences and outcomes per se, but rather children's language ability is. For example, it may be that the quantity of adult speech is most influential in the earlier stages of language acquisition, however the youngest children in my sample were not all at this early stage, some may have progressed further in their language skills. Future research would benefit from larger sample sizes, which are more representative of normed populations, in order to test for this age interaction.

This finding that between the ages of 2 to 4 years, the effect of different types of verbal input on child language and cognitive outcomes does not vary with age has several theoretical implications. First, the age interaction effect may be hidden, second, learning may develop continuously rather than in stages, and third, we require further evidence to form a definite conclusion.

First, it is plausible that specific types of input are more or less important at given ages, but their influence may not be immediately observable in children's expressive language. Therefore, there may be a time lag between the exposure to language input and children actually saying the words they have been exposed to. Perhaps children's receptive vocabulary benefits from specific aspects of adult speech at different child ages, but it is not mirrored immediately in their expressive vocabulary. This idea is supported by Jones and Rowland's (2017) study that reported a time lag of five months between mothers' and children's lexical diversity. The same notion holds for non-verbal cognitive development, a time lag may exist between verbal input and children's non-verbal cognitive outcomes. Therefore, it is not captured by the cognitive ability measure, and longitudinal studies are required to test this assumption.

A second explanation for the lack of interaction with child age is that children's language and cognitive capacity may be continuously constructed from language input rather than occurring at given sensitive periods (i.e., ages). In other words, language input maybe equally and consistently important for children's language and cognitive development in early life, independent of their age. For example, lexically diverse and sophisticated adult speech provides an abundance of phonemes, whose effect on children's vocabulary may be of equal strength regardless of age. Finally, the prior empirical evidence regarding whether child age moderates associations between aspects of language input and child outcomes is weak and contradictory. Therefore, we need better powered research studies which employ longitudinal designs in order to draw a definite conclusion.

7.7 Conclusions

This thesis provides empirical evidence that early life experiences of language, parenting and literacy behaviours are differentially associated with child outcomes. These domain specific associations suggest that different child outcomes have unique environmental predictors and therefore support the environmental specificity hypothesis. In addition, the results of my studies confirm that social interactions within the family home are essential for child development, which aligns with ecological systems and social learning theories. Furthermore, my findings suggest that language input aids linguistic development and therefore provides support for the usage based theory of language acquisition.

Using naturalistic observations of children's home environments provided ecologically valid data to study child development in real-time. Future research into the influence of the home environment on child outcomes would benefit from genetically sensitive, longitudinal research designs, which incorporate multiple methods including naturalistic observations, parent-reports, and standardised tests. By employing more sophisticated analysis techniques such as cross-lagged analysis these studies could provide more insight into the directionality of adult-child interactions to increase our understanding of child development.

7.8 References

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