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Adult–child pedagogical interactions in the home and in preschool: what commonalities can pre-schoolers experience in the context of cognitive development?

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ABSTRACT

Early Childhood Education and Care (ECEC) research emphasizes the importance of adult–child pedagogical interactions at home and in ECEC settings for children's cognitive development. Meanwhile, recent developments in statistics offer the opportunity to challenge gaps in ECEC knowledge fostered by traditional statistical methods.

Aim: Using contemporary statistical mixture modelling procedures: What commonalities exist across the home and preschool in the adult-child pedagogical interactions that children can experience in the context of cognitive development?

Methods: Secondary analysis of data from the Effective Provision of Preschool Education study: 2,857 children and families using 141 ECEC settings across England.

Results: Commonalities are found that vary by pre-schoolers' verbal and nonverbal reasoning. These commonalities reveal the importance of different home learning environments plus opportunities for more equitable and inclusive ECEC. Contemporary statistical methods can reveal new and important ways in which adult–child pedagogical interactions at home and in ECEC settings may shape children's development.

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1. Introduction

A mature body of knowledge exists regarding the effective provision of Early Childhood Education and Care (ECEC); knowledge that has shaped international educational policy and practice for decades (Haslip & Gullo, 2018; Taggart et al., 2008). However, gaps in knowledge remain within this field of enquiry and one such gap concerns the roles played by adult–child pedagogical activities for children's cognitive development during the preschool period (3–4 years). Commonly understood to scaffold child development (e.g. Scharnagl & Smidt, 2024; Frankenberg, 2023), these preschool period activities change over time (e.g. Cox, 2002) and we continue to uncover new trends in their systematic variation across families (e.g. which families engage in more frequent shared parent–child reading; Hayes & Berthelsen, 2020).

One reason that these and other gaps in knowledge remain is that ECEC policy has traditionally placed great stock on research findings from the quantitative approach to research – and yet this

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approach to research, as with all others, has limitations in the types of knowledge that it can return. However, recent developments within the methodology of quantitative research offer ways to challenge some of these limitations and thus present opportunities for researchers who use this approach to address gaps in knowledge and to facilitate the effective provision of ECEC.

Both ECEC and early years interventions are well known to offer sizeable potential benefits to children's development (e.g. Rea & Burton, 2020) and from these benefits, secondary benefits to society (Banerjee et al., 2020). More effective universal ECEC has even been shown to have the potential to facilitate equity in early child development and educational progress (e.g. Hall et al., 2009, 2013). As a result, there now exist a plethora of national policies and supranational guidelines regarding early years policies and practices that aim to foster more effective and more equitable ECEC (e.g. Cascio, 2015) plus more impactful early years interventions (e.g. WHO, 2020).

The key mechanism known to drive the impacts of more effective ECEC (and early years interventions for child development) are adult–child pedagogical interactions (interactions with the intent of teaching) – with 'adults' referring to both parents/guardians and to early years professionals. A broad range of behaviours are included in this term. A recent systematic review in ECEC settings (Howard et al., 2024), for example, groups these interactions into four categories: 1. Building positive (educator-child social-emotional) relationships; 2. Routines and structure ('positive organisation and management of child routines and structure throughout the day' p. 34); 3. Adult–child conversations and questioning ('the use of conversational features that are conducive to fluency, connectedness and joint engagement … … e.g. conversational turns, open-ended questions, cognitive facilitation' p. 35); and, 4. Supporting play (adult facilitation in the context of play). When it comes to interactions within children's homes, a recent systematic review (Harris & Almutairi, 2016) also distinguishes categories of interaction – with these categories broadly mirroring those found by Howard and colleagues (2024).

Considering the magnitude of the impacts of adult–child pedagogical interactions on child development, take, for example, the well-known finding that more stimulating adult–child pedagogical interactions in the home can have effects on the development of pre-schoolers that are larger in size than those associated with growing up in a socially disadvantaged household (e.g. Sylva et al., 2008) and larger than effects associated with the damage to the brain that can occur from low weight and premature births (Wolke et al., 2013). Further, consider also the opposing effects: The literature that reveals those adult–child interactions that can be detrimental to the development of pre-schoolers (e.g. Clarke-Stewart et al., 2002; Goodvin et al., 2008; Martin et al., 2011). Ultimately, the importance of adult-pre-schooler pedagogical interactions is shown in two critical places concerning early years education: Within the 'what matters' of ECEC (namely aspects of 'process quality'; see Sylva et al., 2006) and also within the early years interventions that are designed to support the development of young children (e.g. Head Start in the USA, Puma et al., 2010; Sure Start Children's Centres in the UK, Hall et al., 2019; and others around the world – see OECD, 2001).

However, despite there being a mature and international body of research evidence regarding the importance of adult–child pedagogical interactions in the home and in ECEC settings for pre-schoolers' development, there still remain important gaps in our knowledge. Some of these gaps in knowledge come from the limitations of the quantitative approach to research – the approach to research that continues to inform much early years policy and practice (e.g. Sylva et al., 2004 cited in UNICEF, 2020). This approach to research, for example, frequently implements a deductive 'top-down' representation of the drivers of child development wherein a prespecified set of relationships are hypothesized between a prespecified number of theoretical concepts (and sometimes also within a prespecified number of groups of children/families). In contrast, those theoretical concepts, relationships between concepts, and groups of individuals that are not perceived as important towards answering a given research question are either not measured or are measured but do not feature in the models that are then empirically tested (e.g. within Contextual Value-Added [CVA] models of educational effectiveness where aspects of education are associated with child learning at the end of a given period net of child learning at the beginning of this period as well as background characteristics understood as salient to learning during this period; see Raudenbush,

2004). Of all the consequences of this deductive approach to research (that go beyond the scope of this paper; Wrigley, 2013), one that is particularly damaging is the fostering of a 'Matthew Effect' in ECEC research, policy, and practice (the idea that the 'rich' get richer and the 'poor' get poorer over time; e.g. Van Lancker, 2023). Those concepts and relationships that are believed to be more important to the development of pre-schoolers are more likely to feature in future research, while those that are less researched are pressured to remain so.

A second limitation within the quantitative approach to research that contributes to a gap in contemporary ECEC knowledge regarding the importance of adult–child pedagogical interactions for the development of pre-schoolers comes from *how* this approach to research represents people and their interactions with one another. The quantitative approach to research often implements reductionist notions of the human condition and society (Wrigley, 2019) and these show within research on child development and the potential drivers of child development. This reductionism can be clearly observed in research narratives that describe the 'average' child, family, parent, home, ECEC setting, adult–child interaction (etc.), or even the 'averages' within one or more groups (e.g. Sammons et al., 2002). As a result, the full variation and complexities that exist in humanity, children's development, and the drivers of this development, are impeded from representation within the body of knowledge returned from the traditional quantitative approach to ECEC research (and therefore also within the ECEC policy and practice that it informs). Gaps in knowledge remain – particularly for individuals, adult–child pedagogical interactions, and the contexts within which these interactions occur (e.g. the home and ECEC setting) that are statistically 'non average' (e.g. the development of, and adult–child interactions involving, pre-schoolers with SEND; Research Excellence Framework, 2021). Worse still, these gaps in knowledge regarding the statistically 'non average' are then stubborn to shift due, in part, to the aforementioned Matthew Effect that is fostered by the deduction that also often characterizes the quantitative approach to research.

Of course there are, have always been, and should always be, contributions made to ECEC policy and practice from approaches to research that place less emphasis on deduction and implement less reductionist representations of humanity. Historically, such contributions to research have primarily come from qualitative traditions of research – for which one can find many overviews (e.g. Jarvie, 2012). However, recent advances in the statistical methods available for use in the quantitative approach to research have documented new techniques that are less deductive (instead more inductive) and also less reductionist. Machine Learning approaches are one example (e.g. Gahegan, 2010) and Mixture Models are another (e.g. Dyer et al., 2012; Hodis & Hancock, 2016; Morgan & Padgett, 2021). By dint of their nature, such approaches offer the quantitative approach to ECEC research new opportunities to address the gaps in knowledge that current and historic methods have helped foster in our knowledge of pre-schoolers' development and the role of adult–child interactions (e.g. on persistent under research topic areas, and on groups and processes that are 'non average'). Thus the potential benefits offered by the use of these new statistical methods also extend beyond just the practical (e.g. for the increased external validity of findings). There is also an ethical argument for exploring their use. Matthew Effects fostered by deduction may be impeded and new findings revealed for groups and processes that are statistically 'non average'.

This study responds to the above issues by carrying out a secondary statistical analysis of numeric data regarding pre-schoolers' adult–child pedagogical interactions at home and in their ECEC setting. Data came from, arguably (e.g. UNICEF, 2020) one of the most famous and impactful studies of universal ECEC in the world: The Effective Provision of Preschool Education (EPPE) study (1997–2013; see Sylva et al., 2010; details below). One type of Mixture Modelling (Latent Profile Analysis, LPA) was used to explore the potential for commonalities in the adult–child pedagogical interactions that the EPPE pre-schoolers experienced at home and in their ECEC setting in the context of their association with cognitive development between 3 and 4 years. Findings are compared to those published by the EPPE team, to those from other early years research, and implications are considered for today's contemporary early years policy and practice.

The central research question is:

1 Are distinct (latent) groups evident within the EPPE sample when considering the adult–child pedagogical interactions that pre-schoolers experienced in the home and ECEC setting and how these interactions contributed to cognitive development from 3 to 4 years of age?

Then if distinct (latent) groups are evident within the EPPE sample:

2 How do these groups differ from one another as regards: Adult–child pedagogical interactions, pre-schoolers' cognitive development, and the impact of these interactions on pre-schoolers' cognitive development?
3 What variation in the answers to the above questions exist across the verbal and nonverbal domains of cognitive development from 3 to 4 years of age?

2. Method

Data from the EPPE study (see Sylva et al., 2014) were investigated not only because of the impacts of the EPPE study on ECEC policy and practice around the globe (see above), but also because the EPPE data included detailed information on the adult–child pedagogical interactions that took place in each participating pre-schooler's home and ECEC setting. Furthermore, the EPPE data on adult–child pedagogical interactions during the preschool period (3–4 years) were not homogenized into single numeric scores by the EPPE researchers but were instead specific to different types of pedagogic interaction (see below). In instances where composite scales present within the EPPE data were used in this paper, then corresponding alpha coefficients of scale reliability are reported in the original EPPE Reports: https://www.ucl.ac.uk/ioe/research/featured-research/eppse-publications

Anonymised data from the EPPE study are publicly available online and were accessed from the UK Data Archive (https://beta.ukdataservice.ac.uk/datacatalogue/studies/study?id=7540) for the purposes of this study. Ethical permission for this study was granted by the relevant ethics committee of the British University with which the first author is affiliated. Ethical permission for the original EPPE study was granted by the (then) Institute of Education, University of London.

Of course, in selecting the EPPE data for analysis it was recognized these increasingly historic (1997–2013) and therefore risk reduced relevance for contemporary ECEC policy and practice. The impact of the findings from this secondary analysis for contemporary ECEC policy and practice is therefore explicitly returned to when discussing the findings. The choice to use the EPPE data for this study rather than data from the more recent national study of ECEC in the UK: The Study of Early Education and Development (SEED; University of Oxford et al., 2018), was made because the EPPE data contained eleven measures of adult-pre-schooler pedagogical interactions in their ECEC setting whereas the SEED data contained only two. The comparative richness of the EPPE data was viewed as more important to answering the research questions than was the recency of the SEED data.

2.1. Participants

Participants were the 2857 children (and their families) who participated in the EPPE study (1997–2013) and who attending an ECEC setting during the preschool period (between ages 3–4 years; 1997–1999). Funded by the UK Department for Education, the EPPE study was a longitudinal investigation into the effectiveness of UK ECEC provision for children's development and educational progress. EPPE used a multi-stage stratified random sampling procedure, covering five different geographical regions, and including the six most common types of ECEC setting in the UK at the

time. Of the total achieved sample of 3171 children (and families), only 2857 attended (141) centre-based ECEC settings (the others experienced no ECEC), and both the 3171 and 2857 can be considered broadly representative of their UK equivalent populations at the time (see Sylva et al., 1999).

For the purpose of the current study, only the 2857 pre-school attending children (and their families) were included in the analyses. This due to the necessity for information from all participants on the adult–child pedagogical interactions experienced within each pre-schooler's home and ECEC setting.

2.2. Measures

2.2.1. Adult–child pedagogical interactions during the preschool period

Adult–child pedagogical interactions at home were measured when children were at mean child age 3 years via a Home Learning Environment (HLE) index that merged six items. These six items were considered individually in this analysis in order to maximize the richness of data available on adult–child pedagogical interactions. Each item involved self-report information from parents that was obtained during face to face interviews in the parent's home (at mean child age 3 years). Each item required parents to report the frequency of the adult–child pedagogical interactions that their child was engaging with (at that age) at home using five-point rating scales. The six items were (with response options and descriptive statistics):

1. Frequency child is read to (response options: 1 = rarely, 2 = once a week, 3 = several times a week, 4 = daily, 5 = twice a day; n = 2790, mean = 3.74, standard deviation[SD] = 0.82)
2. Frequency child goes to library (response options: 0 = never, 1 = special occasions, 2 = monthly. 3 = fortnightly, 4 = weekly; n = 2790, mean = 1.13, SD = 1.42)
3. Frequency child plays with letters/numbers (response options as with question number 2; n = 2773, mean = 1.46, SD = 1.01)
4. Frequency parent teaches ABC (response options as with question number 2; n = 2779, mean = 1.48, SD = 0.96)
5. Frequency parent teaches songs/poems/nursery rhymes (response options as with question number 2; n = 2790, mean = 2.28, SD = 1.26)
6. Frequency child paints/draws (response options as with question number 2; n = 2790, mean = 1.99, SD = 0.93)

Adult–child pedagogical interactions at pre-school were measured while the EPPE children were in these spaces (between 3–4 years) and via use of the seven scales of the Early Childhood Environment Rating Scale (ECERS-R; see Harms et al., 1998) and the four scales of the extended ECERS (the ECERS-E) that focusses on activities taking place relative to the early years curriculum that was in place in England at the time (see Sylva et al., 2003). Both the ECERS-R and the ECERS-E use a combination of staff interview and trained fieldworker observations of pre-school rooms/spaces within ECEC settings and both sets of scales involve mean averaging items that were rated using seven-point rating scales (1 = inadequate, 7 = excellent). The seven scales from the ECERS-R are titled (and consider): 'Space and furnishings', 'Personal care routines', 'Language reasoning', 'Activities', 'Interaction', 'Programme structure', and 'Parents and staff' (contributing items are listed here: https://www.ersi.info//ecers_overview.html). The four scales from the ECERS-E are titled (and considered): 'Literacy', 'Maths', 'Science and environment', and 'Diversity' (to meet pre-schoolers' individual learning needs and facilitate gender and racial equality; contributing items are listed here: https://www.tcpress.com/filebin/PDFs/ 9780807751503_subs.pdf). Scores on these subscales are typically used as indicators of the 'quality' of an ECEC setting (e.g. Sylva et al., 2006).

Scores from the ECERS-R and ECERS-E subscales reflect, in varying amounts, the adult-pre-schooler pedagogical interactions that took place in each pre-schooler's ECEC setting. Some subscales reflect direct observation of these interactions (e.g. 'Staff-child interactions' within the

Table 1. Descriptive statistics for the seven ECERS-R & four ECERS-E Subscales.

Seven ECERS-R & Four ECERS-E Subscales	n	Mean	SD
1. Space and Furnishings	141	4.83	1.05
2. Personal Care Routines	141	3.79	1.38
3. Language Reasoning	141	4.31	1.37
4. Activities	141	3.83	1.15
5. Interaction	141	4.79	1.33
6. Programme Structure	141	4.72	1.46
7. Parents and Staff	141	4.07	1.38
1. Literacy	141	3.97	1.08
2. Mathematics	141	2.95	1.18
3. Science and environment	141	2.98	1.51
4. Diversity	141	2.59	1.08

'Interaction' subscale of the ECERS-R) while other subscales capture such interactions indirectly – by assessing the causes and consequences of adult-chid pedagogical interactions in ECEC settings (e.g. the 'Provision for professional needs of staff' item within the 'Parents and staff' subscale of the ECERS-R). Descriptive statistics for the subscales of the ECERS-R and ECERS-E are shown in Table 1.

2.2.2. Cognitive development during the preschool period

At both (mean) age 3 years and at (mean) age 4 years, the 2857 ECEC attendees participating in the EPPE study had their cognitive abilities assessed by trained fieldworkers during home visits and via use of the second edition of the British Ability Scales (BAS; see Elliott et al., 1996). By assessing cognitive abilities at these two time points, the EPPE data allows for narratives on cognitive development across the preschool period. Two sub-domains of cognitive ability/cognitive development were considered in this paper: Verbal abilities and nonverbal reasoning abilities.

Children's verbal abilities were measured at mean age 3 years and at mean age 4 years via scores from two tasks (carried out at both ages), one assessing verbal comprehension (where each child was given spoken instructions and asked to carry them out, e.g. 'Give me the pencil'; age 3 n = 2771, mean = 41.73, SD = 10.13; age 4 n = 2729, mean = 45.65, SD = 8.69), and one assessing naming vocabulary (where each child was shown a picture of an object and asked to name it, e.g. 'horse', 'watch'; age 3 n = 2768, mean = 45.63, SD = 10.35; age 4 n = 2727, mean = 48.66, SD = 10.22).

Children's nonverbal reasoning abilities were measured differently at mean age 3 years and at mean age 4 years (as per standard usage of the BAS). At mean age 3 years, nonverbal reasoning was measured via scores from a 'Picture Similarities' task (where each child was shown a row of pictures and given a card with an additional picture on it; then asked to match this card to the picture with which it shares a link; n = 2816, mean = 46.80, SD = 8.72) and a 'Block Building' task (where a child was asked to copy a two-or three dimensional design shown to them with wooden blocks; n = 2815, mean = 43.57, SD = 9.47). At mean age 4 years, nonverbal reasoning was again measured via scores from two tasks, however, while the Picture Similarities task was repeated (n = 2735, mean = 51.42, SD = 9.279), the Block Building task was exchanged for a task considering 'Early Number Concepts' (where a child was shown squares and pictures and asked to answer questions about numbers, size, and other numerical concepts; n = 2711, mean = 48.75, SD = 8.21).

2.2.3. Characteristics of the EPPE-participating children, families, and ECEC settings

To estimate the association between adult–child pedagogical interactions in the home and ECEC setting and cognitive development from 3 to 4 years of age, it was understood that these associations needed to be considered net of the developmentally salient characteristics of the sampled children, their families, and their ECEC settings. This decision was informed by: 1. The analytic procedures used in the original EPPE study (in order to contribute to a continuous body of knowledge); 2. The EPPE team's shortlist of family and child characteristics understood to foster developmental and educational disadvantage during the early years (the components of their Index of Multiple

Disadvantage); and 3. The Contextualized Value-Added (CVA) model of educational effectiveness that informed the EPPE analysis (see Sylva et al., 2004).

Stratified by ecological level and informed by the many previous published analyses of the EPPE data, sixteen characteristics were considered in this paper: seven relating to each child, three relating to each child's mother, three each child's household, and three each child's ECEC setting. Child, mother, and household variables were self-reported by parents at mean child age 3 years. ECEC setting variables were assessed via setting self-report during the period that the EPPE pre-schoolers were in attendance (from mean 3–4 years). Variables capturing information on these sixteen characteristics are shown in Table 2 (with accompanying descriptive statistics). Dummy variables were created for non-ordinal multinomial variables and Table 2 shows the reference categories that these dummy variables were in reference to via the use of an Asterisk.

2.3. Statistical analysis

Statistical analyses were conducted using SPSS Version 28 (IBM Corp., 2021) and Mplus Version 7.4 (Muthén & Muthén, 2015). Two sets of Latent Profile Analysis (LPA) were carried out to answer research questions 1–3 – one for each domain of cognition (verbal and nonverbal reasoning). Both sets of LPA estimated the existence of latent profiles (groups) within a CVA model that associated adult–child pedagogical interactions at home and in an ECEC setting with cognitive development between 3 and 4 years – contextualized by associations shared with the characteristics of the sample (see Figure 1). These LPA were therefore an application of Mixture Regression Modelling (see Dyer et al., 2012).

The CVA model used in this paper contextualized an individual's likely membership of a latent profile (group). This is a modification of the traditional CVA model which (as per the Introduction) is frequently used in statistical analyses that do not investigate the potential for underlying (latent) groups (e.g. Timmermans & Thomas, 2015). Here, the 'Value Added' element typical of a traditional CVA is unchanged: The associations between adult–child pedagogical interactions at mean age 3 years and mean age 4 cognitive skills are estimated net of the association between cognitive skills at 3 and 4 (either verbal or nonverbal). Latent profiles (groups) were estimated upon the basis of this value-added (statistical) contribution to cognitive development during the pre-school. To have included child, family, and ECEC characteristics both as statistical correlates of likely group membership (as here) and as characteristics of these groups would have been to introduce a circular (statistical) argument (meaning variables would have been associated with themselves).

For the purpose of maximizing the validity of the statistical results from the LPA, these analyses implemented a range of additional statistical modelling procedures including:

1. Implementing the 'BCH' three-step approach to carrying out an LPA that is embedded in Mplus 7.4 (Bolck et al., 2004). The first step estimates the best number of likely latent profiles, the second step estimates the latent profiles, and the third step estimates the statistical correlates of individuals' most likely profile (via odds ratios based on multinomial logistic regression coefficients). Note that the analyses in the third step take account of the uncertainty of an individual's membership of a profile. This is one reason why the BCH approach is preferred to a single step process and extracted latent profile memberships (often in earlier Mixture Modelling papers; e.g. Hall & Wolke, 2012; Herrero Romero et al., 2021).
2. Modelling the nesting of children within preschools via statistical modification of estimated standard errors.
3. Estimation of missing data through use of the Full Information Maximum Likelihood (FIML) procedure. Note that this was only possible in Stage 1 of the BCH LPA process. Neither a FIML or a Multiple Imputation procedure for estimating missing data currently exist when the BCH LPA process is carried out whilst also modifying standard errors to take into account the

Table 2. Characteristics of the EPPE-participating children, families, and ECEC settings that were included as statistical 'covariates' the Latent Profile Analyses reported in this paper.

Ecological level	Variable assessed (using the terminology of the original EPPE study)	*n*	Percentage or mean (standard deviation)
Child	Gender		
	Female	1368	47.90%
	Male	1489	52.10%
	Ethnicity		
	White UK*	2127	74.40%
	Mixed Race	185	6.50%
	White European	118	4.10%
	Black Caribbean	116	4.10%
	Other Ethnic Minority	89	3.10%
	Black African	64	2.20%
	Indian	55	1.90%
	Bangladeshi	25	0.90%
	Other Ethnic Minority	16	0.60%
	First Language		
	English	2622	91.80%
	English as Additional Language (EAL)	235	8.20%
	Number of Changes between ECEC settings		
	No Change	2209	77.30%
	1 Change	628	22.00%
	2 Change	20	0.70%
	Birth Position Amongst Siblings		
	1st born	1254	43.90%
	2nd born	972	34.00%
	3rd born	394	13.80%
	4th born	115	4.00%
	5th born	29	1.00%
	6th born	12	0.40%
	7th born	7	0.20%
	Premature		
	Not Premature	2328	81.50%
	Premature	460	16.50%
	Birthweight Classification		
	Very low birthweight <= 1500 grams	39	1.40%
	Low birth weight 1501–2500 grams	192	6.70%
	Normal/Above Average >2500 grams	2521	88.20%
Mother	Qualification Level		
	None	501	17.50%
	Vocational	423	14.80%
	16 Academic	1048	36.70%
	18 Academic	248	8.70%
	Degree or Equivalent	374	13.10%
	Higher Degree	129	4.50%
	Age (years)		
	16–20	22	0.80%
	21–25	310	10.90%
	26–35	1697	59.40%
	36–45	721	25.20%
	46–55	22	0.80%
	56–65	7	0.20%
	Mother Marital Status		
	Never Married, Single Parent	394	13.80%
	Never Married, Living with partner	405	14.20%
	Married, living with spouse*	1671	58.50%
	Separated/Divorced	299	10.50%
	Widow/Widower	5	0.20%
Household	Household Highest Occupational Status (Mother or Father)		
	Professional Non-Manual	272	9.50%
	Other Professional Non-Manual	748	26.20%
	Skilled Non-Manual	925	32.40%
	Skilled Manual	344	12.00%

(*Continued*)

Table 2. Continued.

Ecological level	Variable assessed (using the terminology of the original EPPE study)	*n*	Percentage or mean (standard deviation)
	Semi-Skilled	361	12.60%
	Unskilled	63	2.20%
	Never Worked	68	2.40%
	Household Total Salary (GBP)		
	No Salary	471	16.50%
	2.5k–15k	426	14.90%
	17.5k–27.5k	392	13.70%
	30k–35k	259	9.10%
	37.5k–66k	458	16.00%
	67.5+k	172	6.00%
	Household Working Status (of Parents)		
	No one working in the house	471	16.50%
	Mum working/Dad not working (or no information)	314	11.00%
	Dad working/Mum not working (or no information)	373	13.10%
	Mum and Dad working*	1020	35.70%
ECEC setting (n=141 ECEC settings)	Number of children per ECEC setting	141	20.26 (5.66)
	Percentage of Mothers with a degree per ECEC setting	141	18.21 (19.71)
	Type of ECEC setting		
	Nursery Class	25	17.70%
	Playgroup	34	24.10%
	Private Day Care	31	22.00%
	Nursery School	20	14.20%
	Combined Centre/Integrated Care	7	5.00%
	Local Authority Day Nursery*	24	17.00%

*Reference category used in the creation of dummy variables.

consequences of a nested sample (here families within preschools). By consequence, BCH Step 2 was carried out on 2068 children and families (72% of 2857) – when considering both the development of pre-schoolers verbal skills and nonverbal reasoning. This limitation is returned to when reflecting upon the findings.

4. Estimation of statistical parameters that were 'robust' to the effects of non-normally distributed variables (via use of the robust maximum likelihood estimator).
5. Z-score standardization of continuous variables in order to facilitate statistical convergence.
6. Replication of the LPA models found to be best fitting (thus indicating the best number of likely latent profiles) but with twice the number of random starts. This to minimize the likelihood of inaccurate results caused by local maxima being achieved from the iterative LPA procedure. The default number of random starts was 2000, this was increased to 8000 to check the solution from the best fitting LPA models (in both cases 200 'best' solutions were taken forward for consideration of best replicated best likelihood values, and 400 iterations were used with each random start).

3. Results

3.1. RQ1: are distinct (latent) groups evident within the EPPE sample when considering the adult–child pedagogical interactions that pre-schoolers experienced in the home and ECEC setting and how these interactions contributed to cognitive development from 3 to 4 years of age?

Contemporary guidelines informed the number of latent profiles that were taken from Step 1 of the two-step LPA process (Dyer et al., 2012; Bakk et al., 2013). This process involved consideration of four statistical estimates of the appropriateness of each LPA model relative to the data to

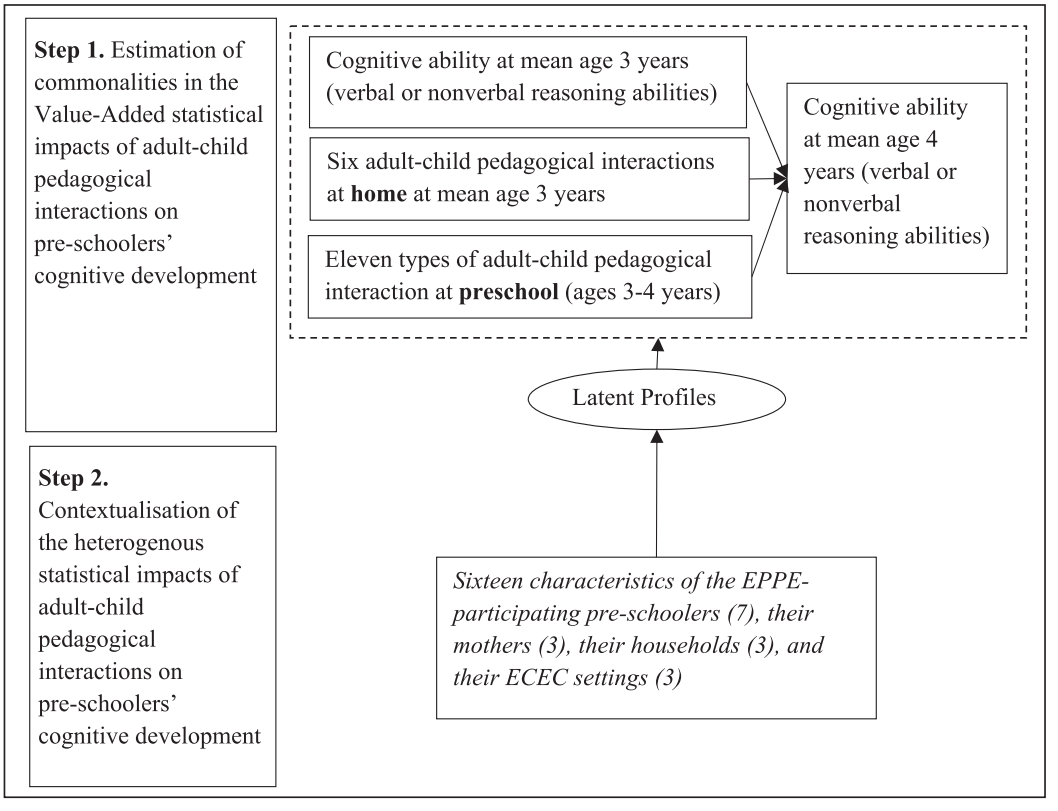

Figure 1. The Contextualized Value Added (CVA) model estimating the association between adult-child pedagogical interactions (at home and in an ECEC setting) and cognitive development between 3 to 4 years estimated within this paper's Latent Profile Analyses (stylized representation of conceptual relationships; see Supplementary Material for example Mplus input). Note: 'Step 1' and 'Step 2' refer respectively to Steps 2 and 3 in the three-step BCH LPA procedure (Bolck et al., 2004; Step 1 in the BCH LPA procedure is estimation of the number of likely latent profiles).

which it was applied (model fit): Statistical Entropy, and three estimates based on Information Criteria (Akaike, Bayesian, and Sample-Size Adjusted Bayesian; AIC, BIC and SABIC). Higher Entropy values (0–1) indicate better model fit (classification of cases to profiles), while the AIC, BIC, and SABIC (all unbounded) indicate better model fit when values are lower. Multiple estimators of fit were considered because the accuracy of each varies depending on different features of a statistical model. Manual inspection of latent profiles was also carried out in order to ensure that profiles were not identified that were merely extreme ends of a population (rather than being unique sub-populations).

Table 3 shows the statistical estimates that evaluated the appropriateness of the LPA models to the data to which they were applied. Combined with manual inspection of the latent profiles (see below), the 4-profile (4 distinct groups) model was taken forward from the models considering verbal abilities and the 5-profile (5 distinct groups) model was taken forward from the models considering nonverbal reasoning. For the 4-profile verbal model, the Entropy value was highest for this model, and the decline in AIC, BIC, and SABIC noticeably smaller for models estimating more profiles (with additional profiles returning only small percentages of cases). For the 5-profile nonverbal reasoning model, the Entropy was the second highest value (differing only 0.01 from the highest), there were more substantial drops in the AIC, BIC and SABIC for this model than with the previous model (estimating 4 profiles) and, importantly, manual inspection of the latent profiles revealed notable substantive differences that are documented below.

Table 3. Latent Profile Analysis (LPA) model fit summary for pre-school period development of verbal abilities and nonverbal reasoning.

Model (with k latent profiles)	Akaike Information Criterion (AIC)	AIC drop (from k-1 model)	Bayesian Information Criterion (BIC)	BIC drop (from k-1 model)	Sample-Adjusted BIC (SABIC)	SABIC drop (from k-1 model)	Entropy	Smallest Profile (%)
Pre-school period development of verbal abilities								
1	72116.36	–	72634.57	–	72358.14	–	–	–
2	70671.85	1444.51	71481.93	1152.65	71049.81	1308.34	0.94	35%
3	69567.33	1104.52	70669.27	812.65	700813.50	968.34	0.96	15%
4	68580.28	987.04	69974.10	695.18	69230.60	850.87	0.98	9%
5	68024.44	555.84	69710.12	263.98	68810.93	419.67	0.97	5%
6	67039.63	984.80	69017.18	692.94	67962.30	848.63	0.91	1%
Pre-school period development of nonverbal reasoning abilities								
1	75510.78	–	76029.02	–	75752.59	–	–	–
2	74047.91	1462.87	74858.04	1170.99	74425.92	1326.68	0.94	35%
3	72877.34	1170.57	73979.35	878.69	73391.54	1034.38	0.98	26%
4	72309.86	567.48	73703.76	275.59	72960.26	431.28	0.94	5%
5	71417.56	892.30	73103.35	600.41	72204.15	756.10	0.97	5%
6	70449.87	967.69	72427.54	675.81	71372.66	831.50	0.88	5%

3.2. RQ2: how do these groups differ from one another as regards: adult–child pedagogical interactions, pre-schoolers' cognitive development, and the impact of these interactions on pre-schoolers' cognitive development?

3.2.1. Pre-school period development of verbal abilities

Table 4 summarizes the differences between the profiles returned from the 4-profile LPA that considered verbal abilities. Full numeric details are provided in the supplementary material. Looking across the four profiles, substantial variation was found in adult–child pedagogical interactions, the development of pre-schoolers' verbal abilities (only 10% showed verbal abilities that matched the average for the whole sample) and how this development was related to adult–child pedagogical interactions in homes and ECEC settings. Adult–child pedagogical interactions in the home mattered for all the EPPE children – particularly how frequently a child was read to – irrespective of verbal abilities at 3 years (entry to preschool) or their development to mean age 4 years (entry to reception).

Beyond the importance of reading at home for the development of verbal abilities, the results summarized in Table 4 also suggest four further differences between profiles regarding the associations between adult–child pedagogical interactions and the development of pre-schoolers' verbal abilities.

First, library usage strongly differentiated the four profiled families with the majority (55%) not using a library at all, and only 35% (Profiles 2 and 4) using a library more regularly than once a month.

Second, there was close correspondence between the average frequency of adult–child pedagogical activities in the home and the average level of verbal abilities at entry to both pre-school and reception (again emphasizing the importance of home learning environments).

Third, pre-schoolers' developing verbal abilities showed varying sensitivity to adult–child pedagogical interactions in ECEC settings that suggests the possibility of a range of conditional compensatory effects that extend existing substantive knowledge gained from prior statistical analyses of the EPPE data (see Discussion below). Adult–child pedagogical interactions in ECEC settings were more likely to be significantly associated with pre-schoolers' developing verbal abilities when:

- A child experienced *average or below average* frequency of HLE activities (Profiles 1 and 3; 65% of children).
- A child experienced *above average* quality of adult–child pedagogical interactions in an ECEC setting (Profiles 2 and 3; 25%).

Table 4. Summary of the differences between the profiles returned from the 4-profile Latent Profile Analysis that considered pre-schoolers' development of verbal abilities.

Variables	Profiles			
	1 (55%)	2 (15%)	3 (10%)	4 (20%)
Mean differences (versus EPPE sample averages):				
Preschool entry verbal abilities:	below average	above average	average	above average
Reception entry verbal abilities:	below average	above average	average	above average
HLE items:	below average	above average	below average	above average
ECERS-R subscales:	average	slightly above average	slightly above average	slightly below average
ECERS-E subscales:	average	slightly above average	slightly above average	average
stand out features?	homogenous library usage (none)	homogenous library usage ('monthly')	homogenous library usage ('special occasions')	very high library usage
What adult-child pedagogical interactions were verbal skills at mean age 4 years sensitive to (statistically associated with) net of verbal abilities at mean age 3 years?:				
HLE items?	sensitive	sensitive	sensitive	sensitive
stand out items:	'Frequency read to'	'Frequency read to'	'Frequency taught ABC'	for picture naming: 'Frequency read to'
ECERS-R subscales?	sensitive	sensitive	sensitive	insensitive
stand out subscales:	for naming vocab.: 'Activities' (although a negative effect)	for picture naming: 'Activities', 'Interactions' (although negative effects)	'Language Reasoning'	–
ECERS-E subscales?	insensitive	insensitive	sensitive	insensitive
stand out subscales:	–	–	'Science and Environment'	–
Suggested Profile Name / Description:	**Majority of pre-schoolers (and families). With below average verbal abilities that are sensitive to adult-child pedagogical interactions**	**Pre-schoolers with above average verbal abilities that are sensitive to adult-child pedagogical interactions**	**Pre-schoolers with average verbal abilities that are particularly sensitive to adult-child pedagogical interactions**	**Pre-schoolers with above average verbal abilities that are particularly *in*sensitive to adult-child pedagogical interactions in preschools**

○ Conversely, if a child experienced below average quality of adult–child pedagogical interactions in an ECEC setting (Profile 4; 20%), then there was little association between these interactions and developing verbal abilities.

- A combination of the above (Profile 3; 10%): *Average or below average* frequency of HLE activities, plus *above average* quality of adult–child pedagogical interactions in an ECEC setting. Further:

○ It was under this combined condition that there was the clearest association between pre-school staff modelling 'Language Reasoning' and the development of pre-schoolers' verbal abilities.

○ This was also the only circumstance under which associations with the development of verbal abilities were found from adult–child interactions linked to the then early years curriculum in England (specific to 'Science and Environment').

Fourth (and finally), there also existed the potential for counter-intuitive associations linking adult–child pedagogical interactions in ECEC settings with the development of pre-schoolers' verbal abilities (see Discussion below).

After the four latent profiles of children were extracted and described (as above), Step 2 of the BCH LPA analysis then revealed ten out of the sixteen characteristics of the EPPE sample to significantly differentiate which of these profiles an EPPE child was more likely to belong to. Statistical

details of how these characteristics significantly differentiated a pre-schooler's likely membership of each profile is provided in the supplementary material. Commonalities in these differentiations revealed, first, that there was very little stratification of profile membership by the economic status of households (especially household salary and highest occupational status). Second, that pre-schoolers with average or above average development of verbal abilities were significantly less likely to attend private day nurseries rather than local authority day nurseries and were less likely to come from a variety of ethnic minority backgrounds (as opposed to 'White British'). Third, that pre-schoolers with above average development of verbal abilities were significantly more likely to have older and more academically qualified mothers.

3.2.2. Pre-school period development of nonverbal reasoning abilities

Table 5 summarises the differences between the latent profiles returned from the 5-profile LPA considering pre-schoolers' development of nonverbal reasoning abilities. Full numeric details are provided in the supplementary material. Looking across the five profiles, substantial variation was found in the development of nonverbal reasoning abilities (only 10% showed nonverbal reasoning abilities that matched the average for the whole sample – as with verbal abilities) and how this development was related to adult–child pedagogical interactions in homes and ECEC settings. Adult–child pedagogical interactions both in the home and in ECEC settings mattered for all the EPPE children - irrespective of nonverbal reasoning abilities at 3 years or their development to mean age 4 years – and no single type of interaction mattered more than any other.

The results summarized in Table 5 also show a variety of differences between profiles (children and families) regarding adult–child pedagogical interactions and their association with the development of pre-schoolers' nonverbal reasoning abilities.

First, pre-schoolers showed above average nonverbal reasoning abilities only when there was also *above average* frequency of adult–child pedagogical interactions in the home (Profiles 1 and 5).

Second, adult–child pedagogical interactions in ECC settings that were tied to the then early years curriculum in England mattered for the development of nonverbal reasoning for 95% of the pre-schoolers (excluding those in Profile 2). Two types of interactions in ECEC settings stood out as of particular importance: Interactions related to the then early years mathematics curriculum and interactions facilitating diversity. However, both these types of interaction only mattered for some children. Interactions related to the then early mathematics curriculum in England mattered only for children who showed *average or above average* development of nonverbal reasoning. Vice versa, interactions facilitating diversity mattered only for children who showed *average or below average* development of nonverbal reasoning, plus, average or *above average* quality of pedagogical interactions in their ECEC setting.

Third (and finally), there was also the potential for counter-intuitive associations linking adult–child pedagogical interactions in an ECEC setting with the development of pre-schoolers' nonverbal reasoning. Particularly for the 'Activities' scale which at above average levels, was associated with slower development of nonverbal reasoning abilities in 75% of the EPPE sample of pre-schoolers (Profiles 1, 3, and 4 in Table 5) (see Discussion below).

After the five latent profiles of children were extracted and described (as above), Step 2 of the BCH LPA analysis showed that twelve out of the sixteen characteristics of the EPPE sample significantly differentiated which of these profiles an EPPE child was more likely to belong to. Statistical details of how these characteristics significantly differentiated a pre-schooler's likely membership of each profile is provided in the supplementary material. Commonalities differentiating the profiles revealed, first, that for pre-schoolers who experienced below average nonverbal reasoning abilities at entry to preschool and development to reception, a more variable quality of ECEC provision (as opposed to average quality provision) was associated with various markers of mother and household socioeconomic disadvantage. Second, that pre-schoolers with average or above average

Table 5. Summary of the differences between the profiles returned from the 5-profile LPA that considered pre-schoolers' development of nonverbal reasoning abilities.

Variables	Profiles				
	1(15%)	2(5%)	3(50%)	4(10%)	5(20%)
Mean level differences (versus EPPE sample averages):					
Preschool entry nonverbal reasoning:	above average	below average	below average	average	above average
Reception entry nonverbal reasoning:	above average	below average	below average	average	above average
HLE items:	above average	below average	average	average	above average
ECERS-R subscales:	slightly above average	inconsistent	average	above average	average
ECERS-E subscales:	slightly above average	inconsistent	average	slightly above average	average
stand out features?	homogenous library usage ('monthly')	almost zero library usage	homogenous library usage (none)	homogenous library usage ('special occasions')	very high library usage
What adult-child pedagogical interactions were nonverbal reasoning abilities at mean age 4 years sensitive to (statistically associated with) net of these abilities at mean age 3 years?:					
HLE items	sensitive	sensitive	sensitive	sensitive	sensitive
stand out items:	'Frequency taught ABC' 'Frequency paints/draws'	'Frequency read to' 'Frequency taught ABC' 'Frequency paints/draws'	'Frequency read to' 'Frequency letter and number play' 'Frequency singing songs or nursery rhymes'	'Frequency paints/draws'	'Frequency read to' 'Frequency taught ABC' 'Frequency letter and number play'
ECERS-R subscales	sensitive	sensitive	sensitive	sensitive	sensitive
stand out subscales:	for picture similarity task: 'Activities' (although a negative effect) for early numbers task: 'Interaction'	'Interaction' 'Personal care routines' 'Language reasoning'	'Activities' (although a negative effect)	'Activities' (although a negative effect)	'Personal care routines', for early numbers task: 'Interaction'
ECERS-E subscales	sensitive	insensitive	sensitive	sensitive	sensitive
stand out subscales:	for picture similarity task: 'Mathematics'		for picture similarity task: 'Diversity'	'Diversity' for picture similarity task: 'Mathematics'	for picture similarity task: 'Mathematics'
Suggested Profile Name / Description:	**Pre-schoolers with above average nonverbal reasoning that are sensitive to adult-child pedagogical interactions and experience higher quality ECEC**	**Pre-schoolers with below average nonverbal reasoning that are sensitive to adult-child pedagogical interactions and experience variable quality ECEC**	**Majority of pre-schoolers. With below average nonverbal reasoning abilities that are sensitive to adult-child pedagogical interactions and experience average quality ECEC**	**Pre-schoolers with average nonverbal reasoning that are sensitive to adult-child pedagogical interactions**	**Pre-schoolers with above average nonverbal reasoning that are sensitive to adult-child pedagogical interactions and experience average quality ECEC**

development of nonverbal abilities were significantly less likely to attend private day nurseries (rather than local authority day nurseries) and were less likely to come from a variety of ethnic minority backgrounds (as opposed to 'White British').

3.3. RQ3: what variation in the answers to the above questions exist across the verbal and nonverbal domains of cognitive development from 3 to 4 years of age?

Perhaps most importantly, adult–child pedagogical interactions in the home were associated with the development of verbal and nonverbal reasoning abilities in all the EPPE children – irrespective of the levels of these abilities at age 3 years, their development to mean age 4 years, or pedagogical interactions with adults in ECEC settings. That said, Tables 4 and 5 show clear differences between the types of interaction in the home that mattered more. For the development of pre-schoolers' verbal abilities, being read to was the most important interaction by far. By contrast for nonverbal reasoning, a much wider variety of interactions were suggested as important (including singing, painting, and drawing).

Outside of the home, adult–child pedagogical interactions in ECEC settings were more frequently associated with the development of pre-schoolers' nonverbal reasoning abilities rather than with verbal abilities. This was the case both for the interactions assessed as part of an overall 'quality' of ECEC provision (assessed by the ECERS-R) and for interactions that were linked to the then early years curriculum in England (assessed by the ECERS-E). By comparison, findings concerning verbal abilities suggested conditional and/or compensatory effects (mitigating effects from less frequent adult–child pedagogical activities in the home) that were linked to adult–child pedagogical interactions experienced in ECEC (see Discussion below).

How the sixteen characteristics of the EPPE sample distinguished the two sets of profiles (for verbal and nonverbal abilities) also revealed important differences and commonalities in how adult–child pedagogical interactions may be associated with pre-schoolers' cognitive development.

First, there was little evidence of a link between household disadvantage and average (or higher) level of quality of provision in an ECEC setting. Greater household disadvantage was linked with a lower chance of experiencing (at least) an average level of quality of provision in an ECEC setting only in children who showed below average nonverbal reasoning abilities (at mean ages 3 and 4 years).

Second, three commonalities distinguished the children and families in the EPPE sample:

1. Average or above average levels of cognitive ability (and development) were more commonly found in children who attended local authority maintained nurseries rather than private day nurseries.
2. Children from some ethnic minority backgrounds showed mean-level differences in cognitive abilities at age three years and development to age four years compared to 'White British' children. (A finding in – keeping with reports of ethnic differences both at the time [Strand, 1999] and to the present day [GOV.UK, 2021])
3. Pre-schoolers with above average cognitive abilities at age 3 years and cognitive development to age 4 years were significantly more likely to have older and more academically qualified mothers.

4. Discussion

The rationale for this paper was two-fold. First, that two facets of ECEC research common in the quantitative approach (deduction and reductionism) have helped foster barriers to our knowledge regarding the development of pre-schoolers and the impacts upon them from adult–child interactions in homes in ECEC settings. Second, that recent advances in statistical methods may help lower these barriers to knowledge by virtue of being both less deductive and less reductionist. The findings from this paper illustrate what recent advances within one of these approaches can achieve in this regard. A Latent Profile Analysis was carried out that combined a three-step sequential approach (Bolck et al., 2004) with Mixture Regression Modelling (Dyer et al., 2012). Results were found to variously mirror and build-upon those found in the previous, more deductive and reductionist, statistical analyses undertaken of the numeric EPPE data. This extension of prior findings is

non-trivial as the EPPE dataset has been subject to statistical analysis since the late 1990s (Sylva et al., 1999).

Regarding the mirroring of past findings from the EPPE dataset, taken together these offer reassurance to researchers that modern advances in more inductive and less reductive statistical approaches need not invalidate the findings from prior statistical analyses that are more deductive and/or reductive. Arguably the most important mirroring of past EPPE findings concerned the impacts found from adult–child pedagogical interactions in the home on all of the pre-schoolers' cognitive development. This echoes findings on the importance of the 'home learning environment' for pre-schoolers' development found in the original EPPE study (e.g. Sammons et al., 2002; Sylva et al., 2010) and supports two continuing narratives in the early years literature. That being read to in the home was the most important adult–child interaction for the development of verbal abilities in the pre-school period supports narratives that look at interactions relative to a specific area of development (cf. 'Home Literacy Environments' and 'Home Numeracy Environments'; e.g. Niklas et al., 2016; Niklas et al., 2020; De Bondt et al., 2020). In addition, that a much wider variety of interactions with parents were suggested as important for the development of nonverbal reasoning abilities (including singing, painting, and drawing) supports narratives that look across multiple types of adult–child interaction and multiple areas of development (e.g. the 'Toddler Home Learning Environment'; Hall et al., 2021).

It is also important to note that our finding of pedagogical interactions in ECEC settings being linked with the development of nonverbal reasoning abilities for all of the EPPE pre-schoolers is in-keeping with continuing understandings in public policy that ECEC has the potential to make a difference in the development of all children and hence warrants continued, if not increased, financial investment from public funds (e.g. World Bank, 2021).

As regards extending past statistical analyses of the EPPE dataset, three sets of substantive findings stand out: 1. That adult–child pedagogical interactions in ECEC settings may provide (partial) conditional compensation for less stimulating home environments for the cognitive development of pre-schoolers; 2. That inclusive practices in ECEC settings may foster the development of nonverbal reasoning in children age 3–4 years, and the conditions under which association occurs; 3. That there was partial socioeconomic stratification of families' use of (at-least) an average quality ECEC setting.

Considering first the suggestion of partial conditional compensatory effects, and as a reminder, these concerned pre-schoolers' developing verbal abilities and were evident under conditions of: higher 'quality' adult–child pedagogical activities in ECEC settings, and less frequent adult–child pedagogical activities in the home. Further, it was under the combination of these conditions that there was the clearest association between development of pre-schoolers' verbal abilities with pre-school staff modelling 'Language Reasoning' plus adult–child interactions linked to the then early years curriculum in England (specific to 'Science and Environment').

These findings advance past EPPE findings in this area (Hall et al., 2009, 2013) which considered only location-specific composite measures of adult–child pedagogical interactions (vis-à-vis measures of the 'home learning environment' and of the 'process quality' and 'structural quality' of ECEC settings). Further confirming the utility of the suite of statistical techniques that this paper highlights, these inductive results are also in-keeping with what many might consider a reasonable deductive hypothesis drawn from the literature on early child development and care. Higher 'quality' modelling of language reasoning with children aged 3–4 years should matter for their developing language skills (e.g. Jokihaka et al., 2022), and that there should be benefits from this modelling coming from non-parent adults – especially when it is less frequently occurring in the home (e.g. McDoniel, Townley-Flores, Sulik, & Obradović, 2022).

In context, keep in mind two things. First, that pre-schoolers showed above average nonverbal reasoning abilities only when there was also *above average* frequency of adult–child pedagogical interactions in the home – a finding entirely in keeping with the well-established literature on the importance of home learning environments for the development of young children (e.g. Gilkerson

et al., 2018). Second, that adult–child pedagogical interactions in ECEC settings were more frequently associated with the development of pre-schoolers' nonverbal reasoning than for verbal abilities. This suggests that adult–child pedagogical interactions in ECEC settings and national curricula during the preschool period may have a greater capacity to affect the development of nonverbal reasoning rather than verbal abilities (for good or ill) – possibly because of the amount of verbal development that often happens before age 3 years (e.g. Elardo et al., 1977).

Considering next the suggestion that inclusive practices in ECEC settings may foster the development of nonverbal reasoning in children age 3–4 years, and the conditions under which association occurs: we see further evidence suggestive of possible compensatory processes. Interactions facilitating diversity in ECEC settings mattered only for children who showed *average or below average* development of nonverbal reasoning, plus, *average or above average* quality of pedagogical interactions in their ECEC setting. This is an important finding because it provides further empirical support for the effectiveness of professional practices towards inclusion in ECEC (cf. Nutbrown et al., 2013) as well as the conditions for these practices – thus helping to inform similar ongoing discussions in contemporary ECEC research (e.g. Morfaki, 2020).

Considering next the partial socioeconomic stratification of the EPPE families' use of (at-least) an average quality ECEC setting: Greater household disadvantage was linked with a lower chance of experiencing (at least) an average level of quality of provision in an ECEC setting – but only in children who showed below average nonverbal reasoning abilities (at mean ages 3 and 4 years). Further, older and more academically qualified mothers were more likely to have pre-schoolers with above average cognitive abilities at age 3 years and then cognitive development to age 4 years.

There are two ways to interpret this finding. On one hand, it is good that adult–child pedagogical interactions in support of pre-schoolers' cognitive development were found to be only partially (rather than completely) stratified by socioeconomic status – results that are in-keeping with EPPE papers showing that early home learning environments, rather than that early socioeconomic status, matters more for long term child development and educational progress (Sylva et al., 2010). On the other hand, it is concerning that the socioeconomic stratification of adult–child pedagogical interactions was found only for the pre-schoolers with below average cognitive abilities. In context, the associations linking parental socioeconomic status, child development, and quality of ECEC provision are complex (re 'education selection effects'; Hall et al., submitted), and the socioeconomic stratification of early child development as well as families access to at-least average quality provision of ECEC remain pertinent issues in the UK (e.g. Playford et al., 2017; Hobbs & Bernard, 2021).

With the suggestion of new substantive findings from the EPPE dataset (now 20+ years old), and results that speak to contemporary theory and research, comes a logical question: To what extent can these findings generalize to contemporary 3–4 year olds, their families, and ECEC settings in England? Understanding that generalisability will be easier where there has been less change over time, there are a variety of data sources that allow for a comparison of these characteristics over time.

Regarding continuity of early child development, between 2006 and 2016 national data revealed disadvantaged pre-schoolers in England had partially caught-up with their peers: there was a reduction of an (average) 5-month gap in attainment to just 4-months by the start of formal schooling (Andrews et al., 2017). Regarding pedagogical interactions in the home and using the same HLE items as EPPE, nationally representative UK data from 2012 suggested that more children were receiving more stimulating pedagogical interactions in the home than at the time of the EPPE study in 1998–1999 (comparing the EPPE averages [reported here] to those reported in Hall et al., 2021). Further, the quality of ECEC provision was also found to rise in the UK from the time of EPPE through to 2014–2016 – as measured at both timepoints by the ECERS-R and ECERS-E instruments used within nationally-representative samples (Melhuish & Gardiner, 2019).

We can therefore suggest that generalizing from the EPPE data to contemporary UK children, families, and/or ECEC settings may not be appropriate because the rate of development seen in the early years has, on average, changed together with observed improvements to pedagogical

interactions in the home and in ECEC settings. However, the data considered above ran only until 2016. Since then and to the time of writing in 2023, the UK has endured a succession of socio-economic challenges. Logically, these risk reducing or reversing the gains shown through to 2016 – but showing this requires new (and ideally regular repetition of) national assessments. Certainly there is anecdotal evidence that 'all may not be well' as regards pre-schooler's development and the conditions within which this occurs (e.g. Newman, 2023). It may be that the reality on the ground is not so different from the late 1990s (as depressing as that may be) – but it would take a large-scale study to show this convincingly.

Beyond the generalisability or otherwise of the findings from the EPPE dataset, it is also important to reflect upon possible reasons for the counter-intuitive associations that were found that linked reduced cognitive development during the pre-school period with higher (not lower) quality adult–child pedagogical interactions in ECEC settings. Five of these associations were found and four concerned the 'Activities' subscale of the ECERS-R, which in contrast to its name, has a stronger focus on a ECEC setting's provision of materials for children to engage with (paint, blocks, sand, music, dress-up, shapes, etc.). Thus, we speculate that the counter-intuitive findings that linked higher scores on this scale to reduced cognitive development may be due to this material facilitating individual play and peer-interactions 'displacing' (e.g. Dore et al., 2020) some kinds of adult–child pedagogical interaction. Speculating further, the presence of these occasional effects, when combined within the wider and otherwise positive associations, may be one reason why the ECERS-R has been repeatedly found to have only moderate associations with child outcomes (Clifford & Neitzel, 2015).

Considering the strengths and limitations of this paper, its strengths centre upon the richness of the data analysed (sample size and representativeness), the range of measurements of adult–child pedagogical interactions in the preschool years (albeit parent-reported interactions in the home), and the ability of the employed secondary analysis to explicitly extend upon the findings from the original high-impact study. Beyond the challenge of analysing the increasingly historic EPPE dataset (discussed above), for example the questionable appropriateness to modern day 'home learning environments' of a question asking after the regularity of trips to the public library, perhaps the key limitation of this paper stems from the state of current procedures for statistical Mixture Modelling. Rapid developments are still being made to these techniques (e.g. adaption and adoption of the BCH approach to LPA used here) and as a result these techniques are not always compatible with others. An example from this paper concerned the restriction on missing data estimation options imposed from needing to combine multilevel statistical modelling with the BCH approach to LPA (limiting use of Full Information Maximum Likelihood and Multiple Imputation for handling missing data). This limitation in the combination of statistical approaches may be regarded as a transitory limitation though, and one common to the development of all new statistical techniques (e.g. the unavailability of multiple imputation for multinomial multilevel data in 2015; Sammons et al., 2015), but it is particularly relevant to educational research with its propensity for hierarchically stratified data.

Looking forward, ECEC research will continue to identify both gaps in knowledge and the barriers that facilitate these gaps. Further, while continued critical engagement with advances in contemporary educational research methods will help researchers to address these gaps and overcome contributing barriers, their capacity to do so relies upon continuing provision of high quality research method training to educational researchers at all levels. In context, consider the recently documented skills gap in statistics knowledge reported in a large sample of Professors of Education in the USA – including in Structural Equation Modelling (Everson, 2022). Of course, the causes of gaps in any field's knowledge, such as which families engage in more frequent shared parent–child reading (Hayes & Berthelsen, 2020), are not solely a reflection of employed research methodology. Rather, in the intrinsically interdisciplinary field of ECEC research (UNICEF, 2020), barriers due to 'silo thinking' (Urban et al., 2019) must also be overcome and in the context of educational Matthew Effects, we encourage more purposeful efforts towards this from the gatekeepers of educational research (funders, editors, employers, and doctoral supervisors).

5. Conclusions

This paper was prompted by recent advances in statistical methods that may help lower long-standing barriers to our knowledge of the complex and varied ways that adult–child pedagogical interactions in homes and ECEC settings may work together to help shape the development of preschoolers' cognitive development. Undertaking a statistical secondary analysis of the publically-available EPPE dataset, the findings from this paper illustrate that modern more-inductive and less-reductionist statistical methods can both mirror and build-upon those found in previous, more deductive and reductionist, statistical analyses such as multilevel modelling and (non-Mixture) Structural Equation Modelling.

The results from this study are also relevant for contemporary ECEC policy and practice plus future studies of inclusion and equity in ECEC. This based on results suggesting: 1. That adult–child pedagogical interactions in ECEC settings may provide a degree of conditional compensation for less stimulating home environments; 2. Conditions under which inclusive practices in ECEC settings may benefit the development of nonverbal reasoning abilities in children between 3 and 4 years of age; and 3. The partial socioeconomic stratification of families' access to (at-least) average quality ECEC. However, the contemporary relevance of these findings, based on 20-year old EPPE data, depends upon comparable expected levels of cognitive development in children aged 3–4 years, and on comparable adult–child pedagogical interactions in the home and in ECEC settings. Whilst improvements in all areas were noted by nationally-representative studies through to mid-2016, recent socioeconomic challenges to the UK raise questions about conditions since then. Recent socioeconomic difficulties in the UK may make the EPPE data more comparable to contemporary UK children, families, and ECEC settings.

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Data availability statement

The (anonymous) data analysed in this paper is freely available to download from the UK ESRC data archive: https://beta.ukdataservice.ac.uk/datacatalogue/studies/study?id=7540.

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