Department for Education

IELS thematic report: Young children's physical development in England

Research report

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[1] The role of the National Advisory Committee was to provide independent advice, guidance and constructive feedback to DfE and NFER on the development and implementation of the study.

IELS outputs overview

The main reports produced for IELS are listed below.

Reports published by OECD

- Early learning and child well-being: A study of 5-year-olds in England, Estonia and the United States (OECD, 2020a). This report looks at the findings as a whole and compares and contrasts the findings across the 3 countries.
- Early learning and child well-being in England (OECD, 2020b). This report focuses on the findings in England.
- Early learning and child well-being in Estonia (OECD, 2020c). This report focuses on the findings for IELS in Estonia
- Early learning and child well-being in the United States (OECD, 2020d). This report focuses on the findings for IELS in the United States
- Early International Early Learning and Child Wellbeing Study (IELS) Technical Report (OCED, 2021). This report provides technical information about the study and data analysis.

Reports published by NFER

- IELS summary report (Kettlewell and others, 2020a), which summarises findings from the IELS national report for England.
- IELS participant report (Kettlewell and others, 2021), which summarises findings for parents and staff in participating schools.

Reports published by Department for Education

- IELS national report for England (Kettlewell and others, 2020b), which builds on the OECD country report for England by further contextualising the findings for England by linking the IELS data with the national pupil database (NPD) and reporting on national questions and an additional measure of physical development.
- IELS thematic report on disadvantage (Classick and others, 2021), which focuses on a more in-depth analysis of the IELS findings on the relationship between children's outcomes and socio-economic disadvantage.
- IELS thematic report on physical development (this report), which focuses on a more in-depth investigation of the findings on children's physical development.

Executive Summary

Introduction

The International Early Learning and Child Well-being Study (IELS) is a new study conducted by the OECD. It seeks to understand children's level of development at age 5, and how this is influenced by their early education experiences, the home learning environment (HLE), and individual and family characteristics. IELS assessed children's emergent literacy (which focused on oral language rather than reading or writing), emergent numeracy, self-regulation and social-emotional development. In England only, children were also assessed on their physical development.

IELS provides an opportunity to explore children's fine and gross motor development and their relationship with other learning outcomes. The analysis in this report has two aims:

1. To identify which factors are related to good levels of fine and gross motor skill development (protective factors) and which factors put children at risk of lower fine and gross motor development.
2. To establish whether fine and gross motor skills are related to 4 other early learning outcomes at age 5: emergent numeracy, emergent literacy, mental flexibility and emotion identification.

This is an underdeveloped area of research, as longitudinal research considering physical development[2] typically focuses on physical health outcomes rather than motor skills development. It is timely to focus on young children's motor skills as children's physical development has been negatively affected by the Covid-19 pandemic (Ofsted 2020a; 2020b; YouGov, 2020; Bowyer-Crane and others, 2021).

The sample comprised around 2,300 children aged between 4 years 11 months and 6 years and 0 months, from around 180 schools. The analysis used multi-level multivariate analysis to identify the relationship between a variable and learning outcome, taking account of the influence of other variables including child and family characteristics (such as age, gender, having an identified special educational need (SEN) and deprivation); aspects of the HLE; and children's attention and persistence.

[2] Such as the Millennium Cohort Study, British Cohort Study and Avon Longitudinal Study of Parents and Children.

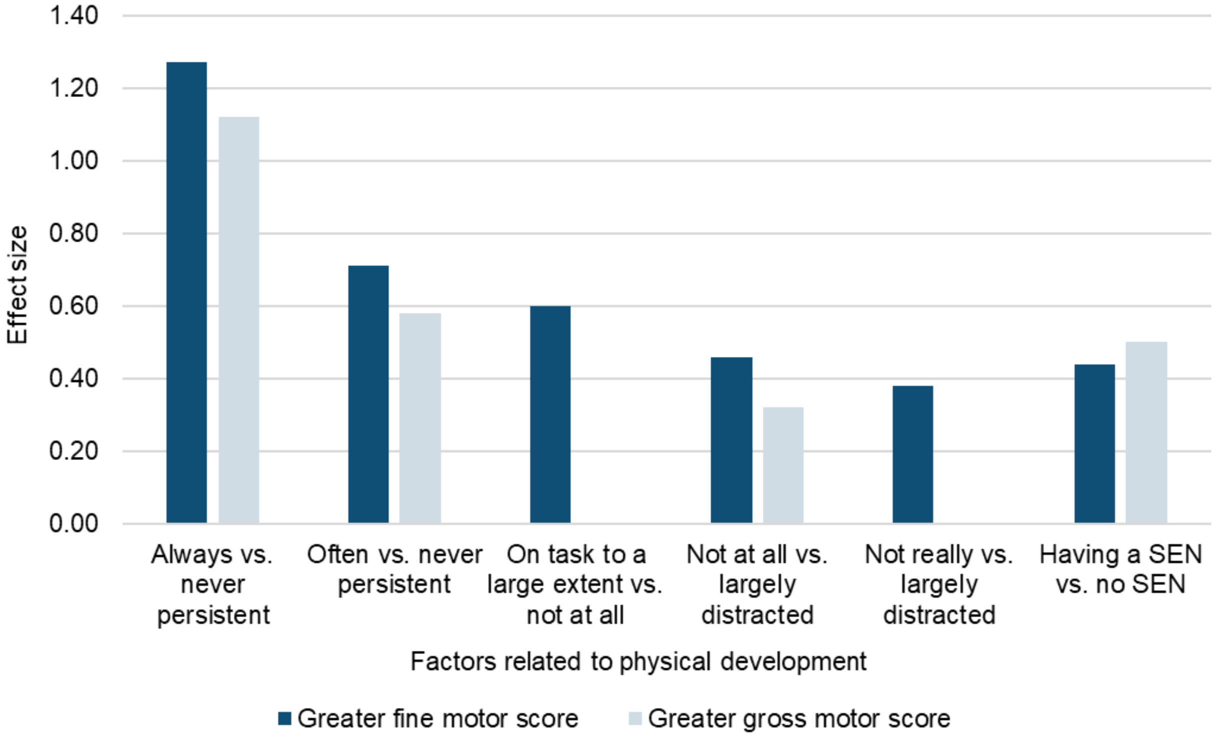
A new contribution to our understanding of children's development at age 5

The existing evidence suggests that motor skills are important in their own right for supporting physical wellbeing, and are a key area of development that appears to be mutually supportive of other cognitive and non-cognitive areas of development (Venetsanou and Kambas, 2010; Livonen and Sääkslahti, 2013; Kettlewell and others, 2020b). Understanding the characteristics that support physical development (protective factors), and those that are associated with lower levels of physical development (risk factors), is important to help teachers, early years practitioners and policymakers to target policies and interventions towards the children who would benefit most. This analysis contributes new evidence on the factors that are related to children's physical development, highlights the interrelated nature of young children's development and points to the potential importance of executive function in underpinning the relationship between physical development and other learning outcomes.

Persistence had the strongest relationship with physical development

Overall, persistence emerged as the protective factor with the strongest positive relationship with both fine and gross motor skills at age 5, after taking account of the influence of other factors, including deprivation. Children's ability to pay attention, as measured by the extent to which they were distracted and the extent to which they were able to remain on task during the IELS direct assessments, was also relatively strongly related to children's physical development, especially fine motor skills. Figure 1 shows the effect size associated with these relationships.

Figure 1 Key factors related to strong fine and gross motor development



Source: IELS assessment of 2,302 children, age 5, England

In IELS, children's persistence was defined as the extent to which a child continues his/her planned course of action in spite of difficulty or obstacles, as assessed by their teachers. The difference in fine motor development was approximately 24 months between children who were always persistent and those who were never persistent, and the difference between children who were often persistent and those who were never persistent was around 14 months.

For gross motor skills, some, but not all of the same factors were significantly related to children's development. Being always persistent (compared to being never persistent) had an effect size of 1.12, while being often persistent had an effect size of 0.58 compared to being never persistent (as age was not statistically significantly related to gross motor skills it is not possible to report associations with gross motor development in terms of months of development).

This appears to be a new finding identifying a relationship between persistence and children's physical development. It may be that the relationship between motor skill development and persistence is underpinned by children's executive function (that is, their higher order cognitive ability) as suggested by Vitiello and others (2011).

Attention is related to physical development

Attention and distraction were both associated with motor development, especially fine motor skills. Children who were rated by IELS study administrators as distracted to a large extent during the direct assessments had lower fine motor skills compared with children who were not at all distracted. This difference is equivalent to about 9 months of development. There was also a significant relationship for children who were not really distracted compared to being distracted to a large extent, with a difference of about 7 months in fine motor skills. For gross motor skills, children who were distracted to a large extent had lower gross motor skills compared to those who were not at all distracted, with an effect size of 0.32.

A similar relationship was found between the children's on-task behaviour during the direct assessments and fine motor development. The small minority of children who were not at all on task had lower fine motor skill development than majority of children who were considered to be on task to a large extent. This relationship had the largest effect size (0.60) among the risk factors identified for fine motor skills – equivalent to about 12 months' difference in fine motor development. There was no such relationship for gross motor skills. Taken together, these findings add to existing evidence of a strong association between a child's ability to focus their attention and their fine motor co-ordination in particular (Kaplan and others, 2002; Piek and others, 2004).

Having a special educational need is a risk factor for poorer physical development

In the IELS sample, 12% of children had an identified SEN (Kettlewell and others, 2020b). Although the majority of these children had difficulties with communication and interaction (such as speech and language difficulties or autistic spectrum disorder) rather than a physical disability or need, having an identified SEN was a significant risk factor for children's physical development. For fine motor development, there is approximately a 9 month difference (an effect size of 0.44) in development between children with an identified SEN and those without. For gross motor development, having an SEN compared to not having an SEN had an effect size of 0.50.

This finding supports previous research showing that the relationship between SEN and physical development is not limited to children with physical needs or disabilities. Evidence suggests that having an intellectual disability can have a negative effect on children's motor skills. For example, children with developmental co-ordination disorder (also known as Dyspraxia), attention deficit-hyperactivity disorder (ADHD) or autistic spectrum disorders often experience motor difficulties due to the cognitive demands of performing complex motor tasks (Piek and others, 1999; Bhat and others, 2011; The Dyspraxia Foundation, 2016). Difficulties with motor skills can be an indicator of unidentified or unmet special needs when considered alongside children's cognitive development (Macintyre, 2009). Identifying children with lower motor skills presents an opportunity for early intervention because motor difficulties are often evident at an earlier age than cognitive indicators of SEN (Macintyre, 2009; Bhat and others, 2011).

Having parents who were involved in activities at their child’s school was a protective factor

Having parents who were strongly or moderately involved with activities at their child’s school was a protective factor for both fine and gross motor skills. Perhaps surprisingly, deprivation was not strongly related to children’s motor development once other factors was taken into account. While being from a background with a higher parental socio-economic status (compared with the average) was a protective factor for fine motor skills, the effect size was quite small. None of the measures of deprivation were related to gross motor development. However, two further characteristics were related to fine motor skills only: being a boy was a risk factor, while being older (closer to age 6 years 0 months than 4 years 11 months) was a protective factor.

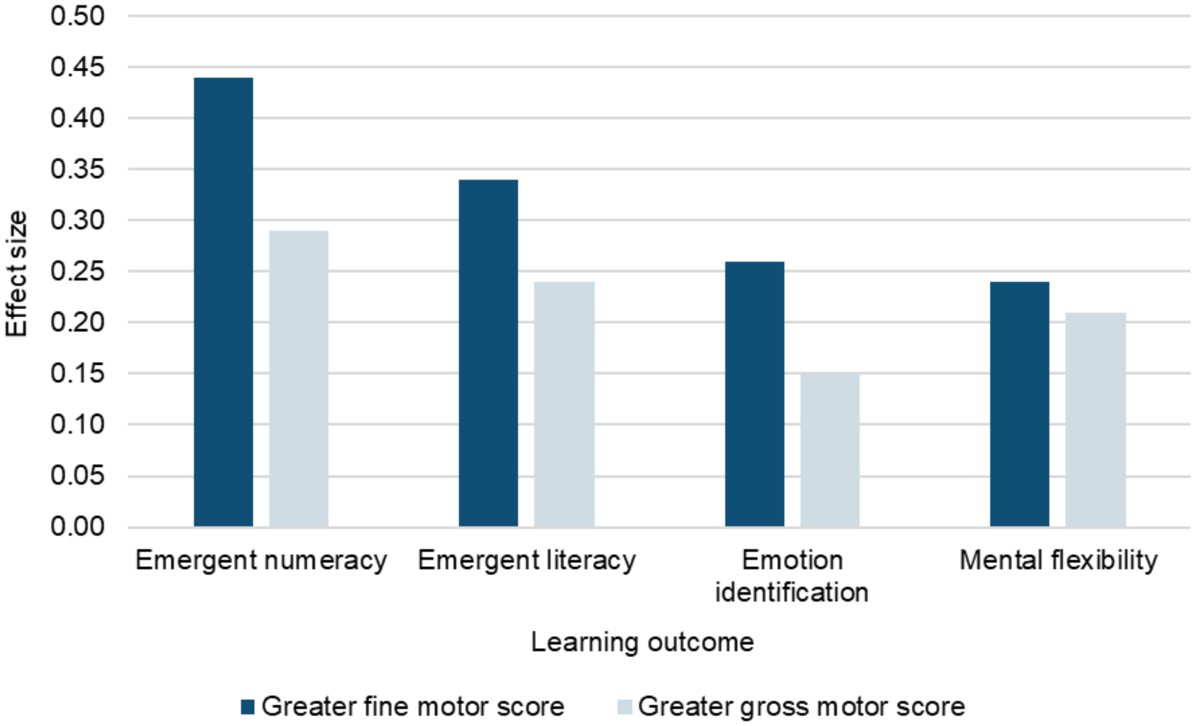
Fine and gross motor development are positively related to 4 key learning outcomes at age 5

There is increasing evidence that physical development is an important predictor of early numeracy and literacy outcomes (Pitchford and others, 2016; Asmussen and others, 2018; Macdonald and others, 2020; Vasilopoulos and Ellefson, 2021). In line with this, the IELS data showed a significant relationship between children’s physical development and oral language skills (emergent literacy) and emergent numeracy.

In addition, this analysis of the IELS data identified significant relationships between children’s physical development and their non-cognitive development in emotion identification (an important part of empathy) and mental flexibility (the ability to shift between rules according to different circumstances). This suggests that the link is not confined to cognitive skills and makes a new contribution to the evidence base. Children who had greater fine and gross motor development had higher emergent numeracy, emergent literacy, emotion identification and mental flexibility outcomes[3].

[3] As fine and gross motor development are continuous variables, the effect size calculated represents the effect of a change in the independent variable (that is, fine motor score or gross motor score) equivalent to its adjusted standard deviation on the outcome of interest.

Figure 2 Relationship between strong fine and gross motor development and children's learning outcomes



Source: IELS assessment of 2,302 children, age 5, England

Fine motor development had stronger relationships with each of the 4 learning outcomes than gross motor development. The relationship with fine motor development is equivalent to approximately 5 months' difference in emergent numeracy and emergent literacy, and to 4 months in emotion identification and mental flexibility. Effect sizes for gross motor development were smaller but still positive, equivalent to approximately 3 months' difference in emergent numeracy and emergent literacy, 2 months in emotion identification and 4 months in mental flexibility.

The findings from IELS add weight to other evidence suggesting that executive function may play an important role in mediating the relationship between physical development and other learning outcomes (Jacques and Zelazo, 2005; Asmussen and others, 2018; Yan and others, 2019; Michel and others, 2020; Vasilopoulos and Ellefson, 2021).

Discussion and conclusion

Persistence, attention, parental involvement and SEN are related to fine and gross motor development

Children's physical development is influenced by a range of fixed and malleable factors. While malleable factors such as persistence and attention are initially shaped by the family environment, these may also be influenced by what happens in early years and school settings (Venetsanou and Kambas, 2010). In contrast, fixed factors, such as having a SEN, can be used by teachers and early years practitioners to identify pupils at risk of lower physical development; and having poor motor skills could potentially indicate that a child may have an unrecognised SEN (Macintyre, 2009; Bhat and others, 2011). This research has identified 2 other fixed risk factors for poor fine motor development: being younger, and being a boy. Fine motor development is known to be important for writing (Dinehart and Manfra, 2013), which is a key skill for children as they enter Year 1. An awareness and understanding of motor skill development, its risk and protective factors, and the relationships between motor skills and other learning outcomes, may help teachers and other early years practitioners intervene earlier to support children's development.

Schools and ECEC settings have an important role in supporting children's physical development

The Covid-19 pandemic has raised concerns about the impact on children's physical development (Ofsted 2020a and 2020b; YouGov, 2020; Bowyer-Crane and others, 2021). It is therefore important for early childhood education and care (ECEC) settings and primary schools to support young children's gross and fine motor skills as part of the Covid recovery process.

Fine and gross motor skills are related to other key learning outcomes

The evidence suggests that young children's physical development is related to other cognitive and non-cognitive areas of development and that these relationships are mutually supportive. This adds to the case for incorporating motor skill development and physical activity, including outdoor play, into the broader framework for early years' provision, and monitoring children's physical development over time. Policymakers and researchers should also consider investigating the role of executive function further to understand how it supports other aspects of young children's development (including fine and gross motor skills).

In conclusion, this study suggests that physical development is more fundamental to children's learning than previously established. Young children's physical development warrants attention in its own right as a key area of development that also appears mutually supportive of other cognitive and non-cognitive areas of learning. These findings are relevant for families, ECEC settings and primary schools, all of which have a key role in enhancing children's physical development.

Glossary

Attention deficit-hyperactivity disorder (ADHD) – a cognitive condition characterised by persistent symptoms of inattention and/or hyperactivity-impulsivity (Piek and others, 1999).

Autistic spectrum disorders (ASD) – a range of disorders comprising 3 subcategories: autism, pervasive developmental disorder, and Asperger's syndrome, which are categorised by a range of social and communication impairments and repetitive behaviours (Bhat and others, 2011).

Developmental co-ordination disorder (DCD) – also known as Dyspraxia, is a disorder affecting fine and/or gross motor co-ordination in children and adults. Individuals may also experience difficulties with cognitive functions such as memory, perception and processing which can impact their planning, organisation and sequencing skills (The Dyspraxia Foundation, 2016).

Early Years Foundation Stage profile (EYFSP) – summarises and describes children's attainment at the end of Reception Year. Children's level of development is assessed against the early learning goals (ELGs) and practitioners indicate whether children are meeting expected levels of development, exceeding them or not yet reaching expected levels.

Effect size (ES) – a statistic showing the magnitude of a relationship between two variables (one of which is the dependent variable) in a population, taking account of the spread of the distribution. It allows comparisons between variables measured via different scales.

Emergent literacy – an IELS tablet-based assessment focused on 3 areas of language and literacy: listening comprehension, vocabulary knowledge, and phonological awareness.

Emergent numeracy – an IELS tablet-based assessment defined as the ability to recognise numbers and to undertake numerical operations and reasoning in mathematics. The measure focused on simple problem-solving and the application of concepts and reasoning in: numbers and counting, working with numbers, shape and space, measurement, and pattern.

Emotion identification – an IELS tablet-based assessment within the social and emotional domain designed to capture children's ability to identify others' emotional states.

Executive function – the higher order cognitive abilities and processes such as working memory, mental flexibility and self-control that enable people to plan, focus attention, remember instructions, and work on multiple tasks.

Fine motor skills – the ability to use the smaller muscles of the hands to achieve small-scale movements, commonly in activities like using pencils and scissors.

Free school meals (FSM) – a measure of economic disadvantage based upon a child's eligibility to be in receipt of free school meals.

Gross motor skills – the ability to use the large muscles of the body for walking, running, sitting, jumping and other activities.

Home learning environment – the combination of both the physical characteristics of the home and the quality of the implicit and explicit learning support children receive from parents[4].

IELS – International Early Learning and Child Well-being Study.

Imputation – the statistical process of replacing missing data with substituted values based on other available information, with the aim of creating a complete dataset.

Income Deprivation Affecting Children Index (IDACI) – an area-level measure of socio-economic disadvantage. IDACI uses information from the Census to measure the proportion of the population in areas experiencing deprivation relating to low income.

Inhibition – a tablet-based assessment within the self-regulation domain of a child's ability to inhibit an impulsive response in favour of an alternative response.

Low birthweight – defined as a being less than 2.5kg at birth.

Mental flexibility – a tablet-based IELS assessment within the self-regulation domain focused on a child's ability to shift between rules according to changing circumstances or to apply different rules in different settings.

National Pupil Database (NPD) – a longitudinal database of all children in maintained schools in England. The NPD is compiled and controlled by the Department for Education (DfE) and contains data from a number of distinct datasets. The NPD includes data on pupil and school-level characteristics (such as age, gender, ethnicity, attendance, eligibility for free school meals) linked to data on national curriculum tests and public examinations results.

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[4] Throughout this report, the term 'parents' is used to refer to children's parents and carers.

Persistence –a rating of the extent to which a child continues his/her planned course of action in spite of difficulty or obstacles.

Self-regulation – characterised by a child's ability to think before acting, persist at an activity, follow directions, remain calm, and control their impulses. In IELS, the self-regulation domain focused on 3 distinct measurements: inhibition, working memory and mental flexibility. These are primarily measures of children's cognitive function (sometimes called 'executive function'), rather than measures of behavioural self-regulation.

Social-emotional learning – a child's ability to begin forming positive relationships with others, to understand and develop behavioural expectations for both themselves and others, and to understand appropriate behaviour in different settings. IELS measured 5 aspects of children's social-emotional development, namely: emotion identification; emotion attribution; prosocial behaviour; trust; and non-disruptive behaviour.

Socio-economic status (SES) – a parental SES index derived from responses given in the parent questionnaire relating to parents' level of education, income and type of employment (OECD, 2020b).

Working memory – a tablet-based assessment within the self-regulation domain focused on a child's ability to store information and manipulate it to complete a given task.

1. Introduction

The International Early Learning and Child Well-being Study (IELS) is a new study conducted by the OECD. It seeks to understand children's abilities at age 5, and how these are influenced by children's early education experiences, the home learning environment (HLE), and individual and family characteristics[5]. IELS measured the development of almost 7,000 5-year-olds across 3 OECD countries: England, Estonia and the United States. In England, the IELS fieldwork was conducted from October to December 2018, with a nationally representative sample of 2,577 children from 191 schools. The study achieved a high response rate in England, with 95% of the sampled schools and 92% of sampled children from these schools taking part.

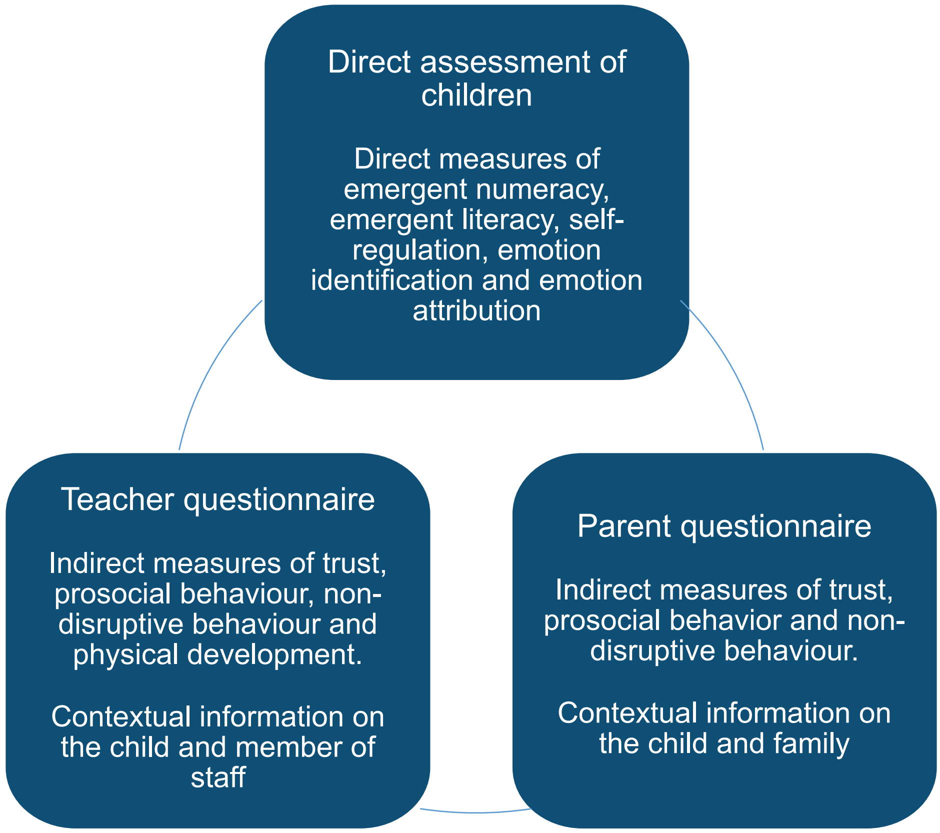
IELS measured children's development in emergent literacy, emergent numeracy, self-regulation and social-emotional development. In England, a teacher assessed module on physical development was added to IELS.

Children were assessed directly by undertaking games and activities on a tablet, supported by a trained and experienced study administrator. IELS also assessed children indirectly, using questionnaires completed by parents and teachers[6]. Most early learning outcomes were assessed both directly and indirectly.

Countries participating in IELS were able to add approximately 5 minutes of national items to the questionnaires and in England a short physical development module consisting of 10 items was included in the teacher questionnaire. This was developed in consultation with national expert, Professor Iram Siraj, and trialled with a small group of Reception and Year 1 teachers. The parent questionnaires also collected information on children's background and the HLE. Figure 3 outlines the data collection methods used.

[5] Note that although the majority of the children were aged 5, the sample also included some younger children who were aged 4 years 11 months and some older children who were aged 6 years 0 months at the time of assessment.
[6] Around 67% of parents completed the parent questionnaire and around 90% of teachers completed the teacher questionnaire. For full details, see Appendix A.

Figure 3 The different elements of IELS data collection



The IELS data for England was linked to the national pupil database (NPD). This provides a more comprehensive set of data on a wide range of pupil characteristics including ethnicity and special educational needs (SEN) than was available through the IELS dataset alone. The NPD also provided contextual information about the children in the sample that was important within the England policy context, such as eligibility for free school meals (FSM).

What is the focus of this report?

This report builds on the IELS national findings for England (Kettlewell and others, 2020b) by further exploring children's physical development, specifically in relation to their fine and gross motor skills, using multivariate analysis. This report will explore the following research questions.

1) Which factors predict good physical development (in fine and gross motor skills) at age 5?

2) Is young children's physical development (in fine and gross motor skills) predictive of other early learning outcomes at age 5?

A note on statistical prediction

In relation to statistical analysis, 'prediction' means the extent to which there is an association between an independent variable and an outcome measure which is unlikely to have occurred by chance. This report uses multivariate multi-level models, which take account of the influence of other predictor variables and the inherent structure of the data whereby pupils are 'nested' within schools. The predicted value of each variable represents the strength of an association once the influence of other variables in the model have been taken into account. However, it does not mean that the association is necessarily causal, nor should it be assumed that the results can be used to predict an association between a variable and an outcome at a later point in time.

IELS provides an opportunity to explore children's fine and gross motor skill development, which is an underdeveloped area of research. This is because longitudinal research into physical development[7] typically focuses on physical health and wellbeing outcomes rather than motor skill development. However, recent evidence (which is discussed later in this report) suggests that motor skills are important in their own right for supporting physical wellbeing and appear to support other cognitive and non-cognitive outcomes.

The Covid-19 pandemic has brought renewed attention to the importance of motor skills, particularly in relation to school readiness, as school leaders have raised concerns about children losing key motor skills and confidence in their motor abilities during the period they did not attend school (Ofsted 2020a; 2020b; YouGov; 2020). Furthermore, the importance of motor development in early childhood development is reflected in the changes to the EYFSP which has separate early learning goals (ELGs) for fine and gross motor skills (DfE, 2020). Therefore, this thematic report provides a timely opportunity to use the IELS data to examine young children's fine and gross motor skills and the relationship these skills have with other learning outcomes.

Chapter 2 considers whether certain factors are protective or risk factors for fine and gross motor skill development at age 5, including their individual and family characteristics, home learning environment and early education experiences. Chapter 3 then looks at whether these aspects of physical development are predictive of 4 other early learning outcomes at age 5: emergent numeracy, emergent literacy, mental flexibility and emotion identification. Chapter 4 discusses the implications of this evidence.

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[7] Such as the Millennium Cohort Study, British Cohort Study and Avon Longitudinal Study of Parents and Children.

Methodology

A similar analytical approach was used for both research questions. The analysis primarily used linear multi-level modelling to test whether independent variables (such as children's age, gender and aspects of the home learning environment) were significant predictors of the learning outcomes (listed below). Multi-level modelling was used to account for the clustering of children within schools. A two-stage process was used for each model to identify the independent variables that significantly predicted the dependent variable individually and then improved the predictive ability of the final model. As a result, the analysis identified which variables had the strongest predictive power and modelled their relative effects taking other variables into account. Further details on the methodology are available in Appendix A.

For all models, 4 categories of independent variables were included: NPD variables; child dataset variables; parent questionnaire variables; and teacher questionnaire variables. However, please note that, due to the need to avoid identifying individual research participants, any analysis resulting in cell sizes of less than 10 has been supressed and the related findings are not described in this report. To comply with rules on avoiding disclosure, additional cells may have been suppressed if their inclusion resulted in the calculation of the supressed cell. Further details on the variables included in each model can be found in Appendix C.

The analysis focused on 4 learning outcomes in addition to fine and gross motor skill development. These were all direct measures of children's development, rather than indirect measures assessed by teachers.

- **Emergent literacy**[8] and **emergent numeracy** – chosen for their well-documented importance for children's development and education policy
- **Mental flexibility** – a self-regulation measure of children's ability to shift their thinking according to the circumstances; chosen due to its correlation with physical development and other learning outcomes
- **Emotion identification** – a social emotional measure of children's ability to identify other people's emotions; chosen due to its relationship with physical development and other learning outcomes.

These 4 learning outcomes were chosen to provide a breadth of measures across different domains. All 4 learning outcomes included in this report are also explored in a

[8] Note that emergent literacy focused on oral language rather than reading or writing.

second thematic report using IELS data (Classick and others, 2021), which looks in more detail at the influence of deprivation.

Prior to conducting the analysis, the research team needed to address the issue of missing data. Aside from the learning outcome measures, data for all variables required imputation. This affected data from the parent questionnaire in particular (such as parental SES, number of siblings, low birthweight and the HLE), as 33% of parents of participating children did not complete the parent questionnaire. For details on the imputation methodology and variables where imputation took place, see Appendix A.

No imputation was required for the measures of fine and gross motor development. If children had any missing responses on the 5 items used for constructing either of these measures then they were removed from the relevant dataset (that is, from the dataset for either fine or gross motor development). After excluding children on this basis, the fine motor dataset contained 2,249 children from 183 schools and the gross motor dataset contained 2,197 children from 182 schools. The final fine and gross motor datasets were both representative of the schools who took part in IELS. Full details on the checks carried out on the fine and gross motor datasets can be found in Appendix B.

What is already known about children's physical development?

Physical development is a key area of children's early development (Asmussen and others, 2018; DfE, 2018a; Shuey and Kankaras, 2018; Sim and others, 2018). It features as one of 3 prime areas of learning within the EYFS, alongside communication and language development and personal, social and emotional development. The way children develop physically is established by genetic factors and influenced by environmental factors (Venetsanou and Kambas, 2010). There are 3 main influences on children's physical development: the characteristics of the child; the characteristics of their family; and their environment.

The existing evidence suggests that the following child and family characteristics are positively associated with children's physical development, especially in the period from birth to 5.

- Being older (that is, maturation) (Livonen and Sääkslahti, 2013)
- Not having an identified special educational need (SEN) such as Developmental Coordination Disorder (DCD), Attention deficit hyperactivity disorder (ADHD) and Autism spectrum disorders (ASD) (Piek and others, 1999; 2004; Greens and others, 2009; Macintyre, 2009; Asonitou and others 2010; Bhat and others, 2011)
- Not having experienced low birthweight or premature birth (Burns and others, 2004; Quigley and others, 2012; Zwicker and Harris, 2013; Asmussen and others, 2018)

- Being more physically active (Cliff and others, 2009; Bürgi and others, 2011; Livonen and Sääkslahti, 2013)
- Having older siblings (Venetsanou and Kambas, 2010; Livonen and Sääkslahti, 2013)
- Having a mother with a higher level of education (Venetsanou and Kambas, 2010; Asmussen and others, 2018)
- Being from a more affluent background. (McPhillips and Jordan-Black, 2007; Venetsanou and Kambas, 2010).

There appears to be a complex relationship between gender and physical development in young children, with some aspects of physical development being positively associated with being a girl while others are positively associated with being a boy (Livonen and Sääkslahti, 2013; Kokštejn and others, 2017). For example, Livonen and Sääkslahti (2013) found that being a boy was associated with better manipulation skills, while being a girl was associated with better locomotor and balance skills.

Children's home environments and ECEC settings are important venues for physical development as they afford opportunities for children to develop and practice their motor skills. Some family environments appear to enable children's physical development via encouragement, modelling behaviour and interactions with adults and peers (Venetsanou and Kambas, 2010; Davids and Roman, 2014). ECEC provides additional opportunities for children's physical development, through providing space, equipment, dedicated time and implementing programmes specifically aimed at promoting children's physical development (Venetsanou and Kambas, 2010; Livonen and Sääkslahti, 2013).

There is growing evidence that physical and cognitive development are related, and that cognitive and motor skills are mutually supportive of one another (Rosenbaum and others, 2001; Macintyre, 2009; Venetsanou and Kambas, 2010; Burns and others, 2014; Van der Fels and others, 2015; Harvey and Miller, 2017; Schmidt and others, 2017; Zeng and others, 2017). The relationship between physical and cognitive development appears to be mediated by executive function. Executive function refers to higher order cognitive abilities and processes used for planning, processing information, problem-solving and metacognition in goal-directed behaviour (Miyake and others, 2000; Zelazo and others, 2003; Verdine and others, 2014; Serpel and Esposito, 2016; Ackerman and Friedman-Krauss, 2017). Executive function is particularly important for complex and co-ordinated movements (Van de Fels and others, 2015). For example, moving with balance, control and co-ordination and being able to manipulate objects are key motor abilities which are dependent on cognitive abilities such as the individual paying attention, remembering what to do to achieve a movement, and using feedback from previous attempts to improve the next attempt (Macintyre, 2009). However, there is also evidence that cognitive and physical development operate independently of one another to influence cognitive outcomes (Cameron and others, 2012). There is little evidence on the relationship between young children's physical development and their self-regulation or social-emotional skills.

Motor skills are learned sequences of movements needed to achieve a particular task, and may be divided into fine and gross motor skills (Van der Fels, 2015). Fine motor skills require precision and smoothly integrated movements, while gross motor skills typically require strength, agility, flexibility and balance (Van der Fels, 2015). The available evidence suggests that academic performance is more strongly related to fine motor skills than gross motor skills. There appears to be stronger evidence for a link between fine motor skills and numeracy than between fine motor skills and literacy (Timmons and others, 2007; Grissmer and others, 2010; Dinehart and Manfra, 2013; Clements and others, 2016; Pitchford and others, 2016; Asmussen and other, 2018; Suggate and others, 2019; Macdonald and others, 2020; Michel and others, 2020). The evidence suggests that fine and gross motor skills support children's conceptual knowledge of key principles such as counting (Asmussen and others, 2018) and that executive functions such as working memory and spatial attention may mediate the relationship (Le Fevre and others, 2010; Michel and others, 2020).

The overall EYFSP results for children attending Reception in 2018[9] (DfE, 2018b) and the results of initial (bivariate) analysis in the national report for England (Kettlewell and others, 2020b) are broadly consistent with the evidence on physical development and motor skills presented above. Both sets of results show that lower physical development outcomes overall were associated with the following characteristics: being a boy, being younger within the year group, being eligible for free school meals (FSM) and having an identified SEN (DfE, 2018b; Kettlewell and others, 2020b). The initial analysis of IELS results also found that having experienced low birthweight was associated with lower physical development outcomes (Kettlewell and others, 2020b). The EYFSP results found that children with English as an additional language (EAL) had lower physical development outcomes than their peers (DfE, 2018b). Furthermore, the EYFSP results found a relationship between children's ethnicity and their physical development, whereby children from a Chinese background scored more highly than the average for all children, and children from Asian and Black backgrounds scored slightly lower than the average for all children (DfE, 2018b). However, the IELS national report for England (Kettlewell and others, 2020b) did not detect a significant relationship between EAL status or ethnicity and physical development. This may be due to the much larger sample included in the national EYFSP results than in the IELS sample.

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[9] The majority of the IELS sample were in Reception class in the summer of 2018, when the EYFSP assessments were made.

The bivariate analysis of the IELS results in England (Kettlewell and others, 2020b) also found that greater physical development was associated with the following characteristics of the HLE: drawing or painting regularly, being taken to a special or paid activity outside of the home (for example, sports clubs, dance, swimming lessons, language lessons) on a regular basis and having more than 100 children's books in the home. Finally, the bivariate analysis found that physical development was correlated with all of the other learning outcomes, which is consistent with the research discussed above suggesting that children's development at age 5 is interrelated. Mental flexibility and emotion identification were found to have the strongest correlations with children's physical development (Kettlewell and others, 2020b).

How were the fine and gross motor skill measures developed?

As described above, the IELS team in England developed a measure of children's physical development based on teacher ratings. The physical development items were intended to be similar to the 2018 EYFSP early learning goal 04 – moving and handling – and to capture a range of areas of fine and gross motor skill development. This measure was administered via the teacher questionnaire, where teachers were asked to rate each child on each item using a 5-point scale[10].

Given the existence of different findings for children's fine and gross motor skills in the wider evidence-base (Livonen and Sääkslahti, 2013; Asmussen and other, 2018; Macdonald and others, 2020), the IELS team investigated whether it was possible to split the overall measure into two separate measures representing children's fine motor skills and gross motor skills. This proved successful, resulting in two robust measures and allowing the research to provide a more fine-grained understanding of children's physical development. Table 1 shows the items that were included in the fine and gross motor scales (see Appendix B for further information).

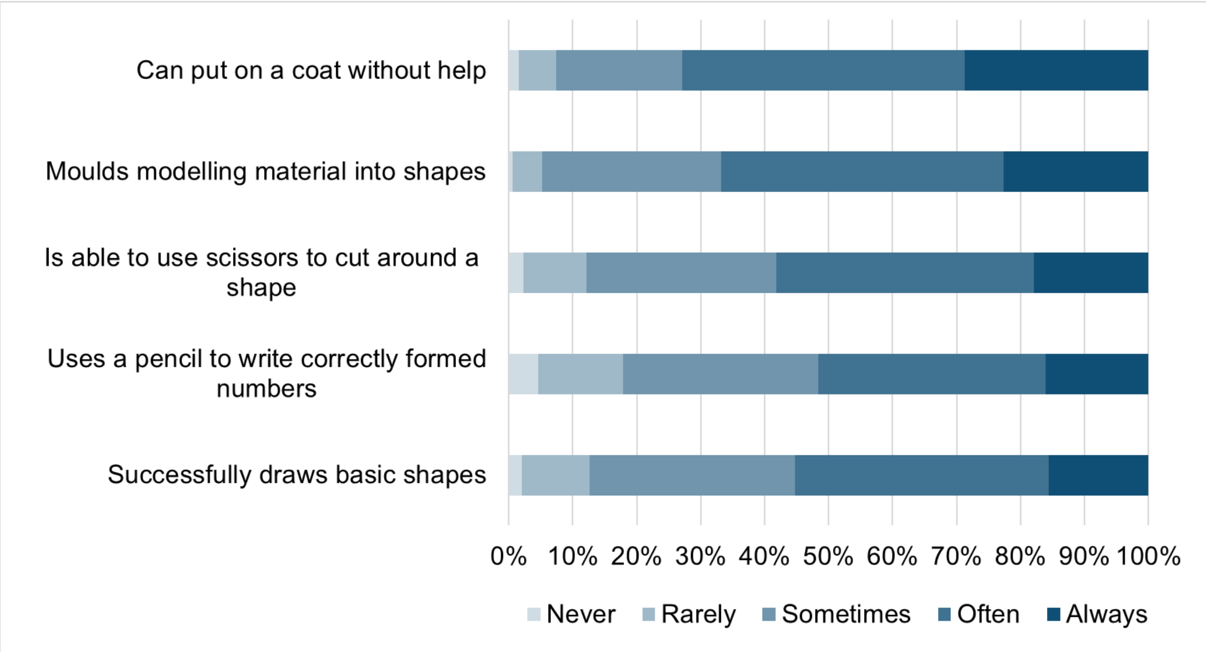
[10] The teacher questionnaire asked teachers to rate how often each child successfully completed each motor skill item on a 5-point scale: 'Never', 'Rarely', 'Sometimes', 'Often' and 'Always'.

Table 1 Physical development items

Fine motor skill items	Gross motor skill items
Putting on a coat without help, including buttons and zips Moulding modelling material into shapes Using scissors to cut around a shape[11] Using a pencil to write correctly formed numbers Drawing basic shapes	Using large-scale equipment confidently Jumping off objects in a controlled way Negotiating space when running Catching objects

Figures 4 and 5 show the overall distribution of teachers' answers to each item grouped by fine and gross motor skills separately. Note that the items are listed in order of difficulty (from highest to lowest percentage of children whose teachers rated them as 'always' being able to demonstrate each skill), rather than the order in which they appeared in the questionnaire.

Figure 4 Components of the fine motor skill measure

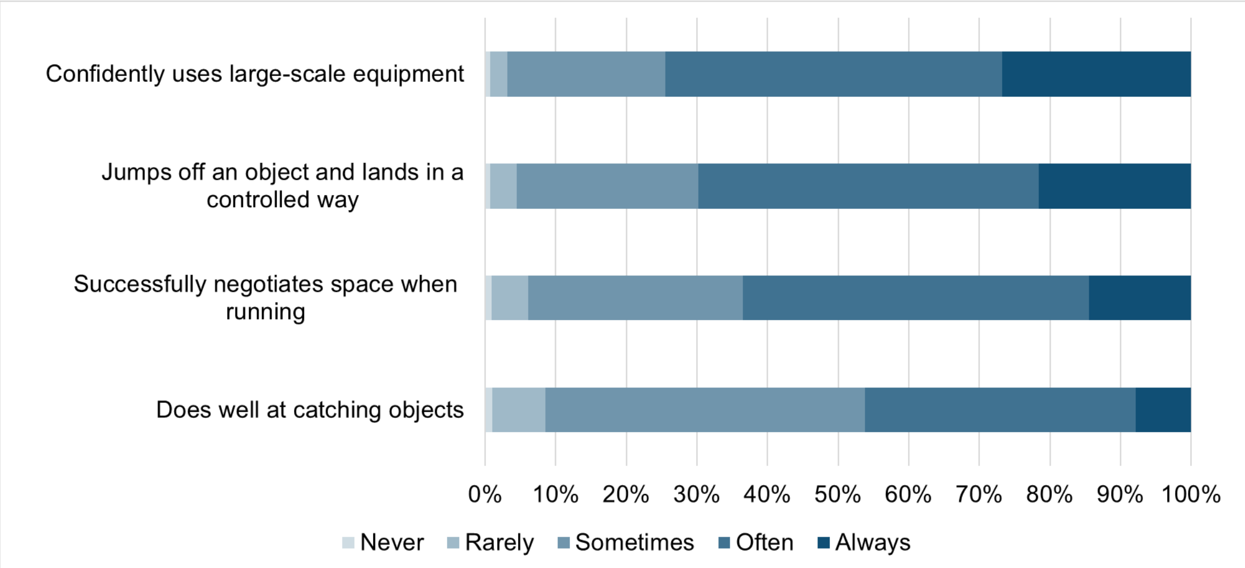


Source: IELS assessment of 2,249 children, age 5, England

[11] Kettlewell and others (2020) excluded this item from the overall measure of physical development due to evidence of bias by gender. However, it was able to be included in the measure of fine motor development because splitting the items into fine and gross motor skills removed the issue.

Of the 5 fine motor skill tasks included in the measure, 5-year-olds were most able to put on a coat without help, including zips and buttons: teachers assessed 73% of children as able to do this ‘always’ or ‘often’. Conversely, just 52% of children were rated as always or often able to use a pencil to write correctly formed numbers. This item also had the highest proportion of children rated as ‘never’ or ‘rarely’.

Figure 5 Components of the gross motor skill measure



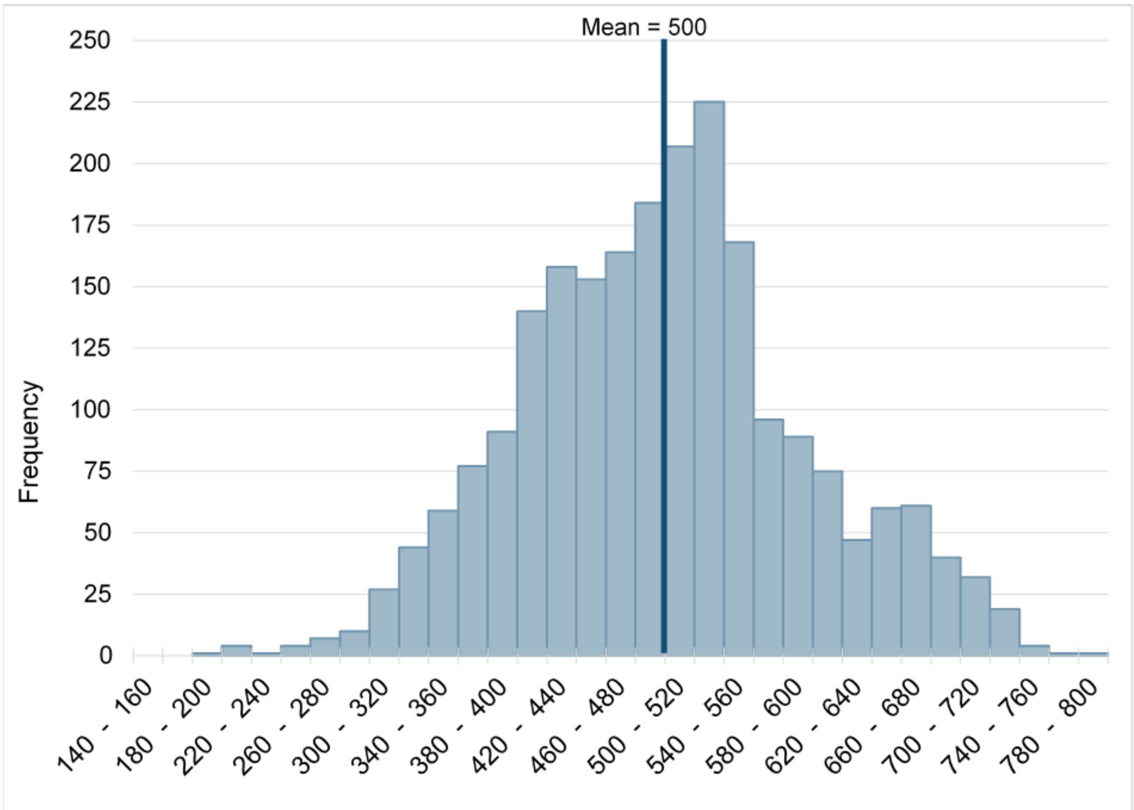
Source: IELS assessment of 2,197 children, age 5, England

The measure of gross motor skills included 4 items. Teachers judged that 75% of children were ‘always’ or ‘often’ able to use large-scale equipment confidently. In comparison, only 46% of children were rated ‘always’ or ‘often’ to do well at games or activities involving catching objects.

Item response theory (IRT) analysis demonstrated that the items did group together to form two discrete measures of fine and gross motor skill development. The two resulting measures were found to be reliable, meeting the acceptable criteria for measures and not displaying any bias by gender (see Appendix B for further information). Both the fine and gross motor scales had Cronbach’s alpha scores of 0.90, which indicates the scales are highly reliable.

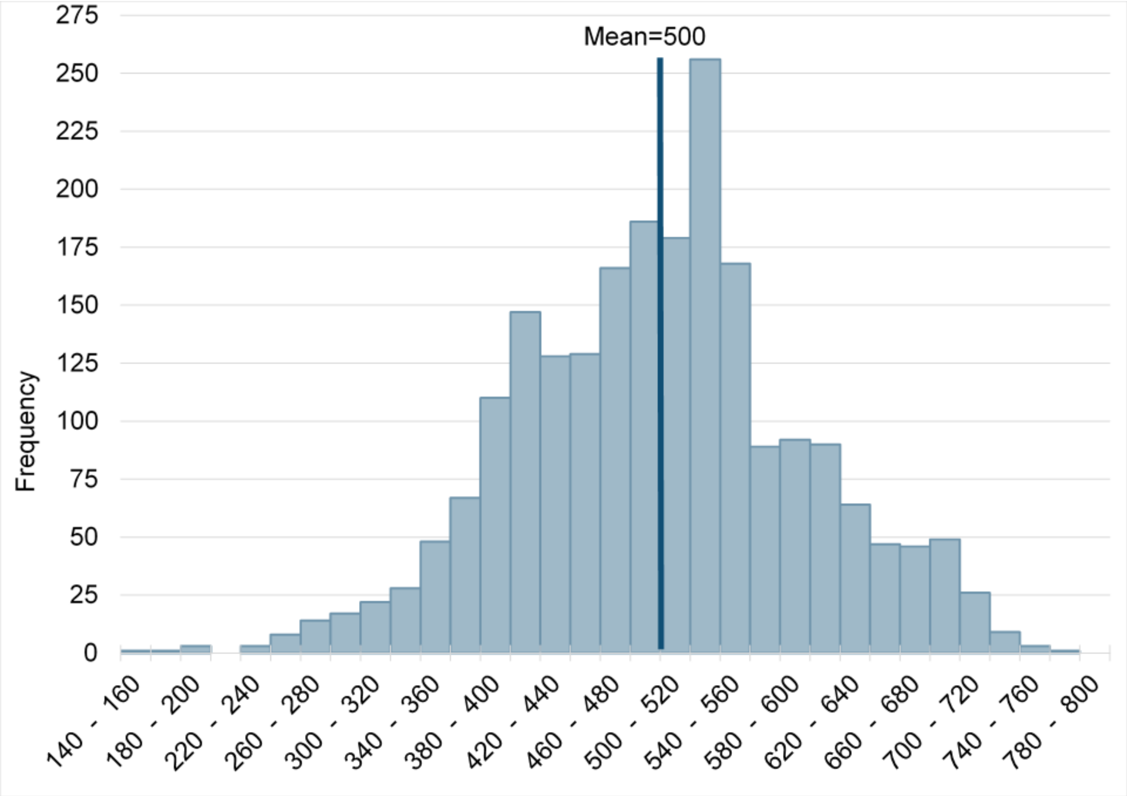
The IELS fine and gross motor skills measures were both scaled to have a mean of 500 points and standard deviation of 100 points so that they were consistent with the international learning outcomes for the other domains. Figures 6 and 7 show the distribution of the children’s fine and gross motor skill outcomes.

Figure 6 The distribution of children's fine motor skill development outcomes



Source: IELS assessment of 2,249 children, age 5, England

Figure 7 The distribution of children's gross motor skill development outcomes



Source: IELS assessment of 2,197 children, age 5, England

The distributions of the standardised mean scores for the both fine and gross motor skills are almost normal in their appearance and are acceptable from a psychometric point of view.

2. Which factors predict good physical development at age 5?

Chapter summary

Understanding the factors that support physical development or put children at risk of lower levels of physical development is important for helping teachers, early years practitioners and policymakers to target policies and interventions towards the children who would benefit most. This chapter identifies which factors were found to predict children's fine and gross motor development, after taking account of the influence of other variables included in the models.

- Being always or often persistent compared to being never persistent and having parents who were strongly or moderately involved in their school (compared to having parents who were slightly/not involved) were associated with greater development in both fine and gross motor skills.
- Having an identified SEN and being distracted to a large degree during the direct assessment were risk factors associated with lower development in both fine and gross motor skills.
- Being older at the time of the assessment and from a higher parental socio-economic status (SES) background were protective factors associated with greater development in fine motor skills.
- Being unable to stay on task at all during the direct assessments and being a boy were risk factors associated with lower development in fine motor skills.
- The variables included in the fine motor model accounted for 39% of the variance in children's fine motor development[12], whereas the variables in the gross motor model explained less of the variance in children's gross motor development (22%). Models that explain below 50% are quite normal and ultimately show that there are other factors, that have not been measured, that explain more of the variation in the outcome of interest. These other factors could be many in number given the variety of possible influences on young children's learning outcomes.

[12] Note that some percentages have been rounded to the nearest whole number here and elsewhere in the report.

Overview of the statistical models

This analysis used linear multi-level modelling to examine the association between different variables and children's motor skill development. Separate models were used for fine motor skills and gross motor skills. A large number of child, family and school variables drawn from different sources were tested in the modelling, many of which did not appear to be statistically significantly related to fine motor skill development. To be included in the final model, the variable had to be significantly related to the dependent variable individually and then had to improve the predictive ability of the multi-level model over and above the other variables in the model.

The methodology section in Appendix A explains how the multi-level models were developed and how it was determined that a particular model was the final model. The amount of child-level variation explained by the final models provides an additional piece of information which can be used to understand how informative the individual models are and to allow comparisons between models.

The final model examining factors associated with fine motor skills accounted for 39% of the variance in children's fine motor development. It included the following variables:

- Child characteristics (gender, age, FSM eligibility and SEN)
- Socio-economic status of the parents (the IELS SES index)[13]
- Children's behaviour during the direct assessments[14] ('Was the child easily distracted?' and 'Did the child stay on task?', as assessed by the study administrators)
- Children's ability to be persistent (the extent to which a child continues his/her planned course of action in spite of difficulty or obstacles, as assessed by their teachers[15])
- Parental involvement with activities at their child's school (teacher-rated)[16].

The final model examining factors associated with gross motor skills accounted for 22% of the variance in children's gross motor development. It included the following variables.

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[13] This a variable derived by OECD and based on parental occupation, parents' level of education and household income.
[14] Study administrators were asked to evaluate each child's level of distraction and 'on-task' behaviour on a 4-point scale ('yes, to a large degree', 'yes, to some degree', 'no, not really' or 'no, not at all').
[15] Teachers were asked to rate the extent to which the child continue his/her planned course of action in spite of difficulty or obstacles on a 5-point scale ('never', 'rarely', 'sometimes', 'often' or 'always').
[16] The teacher questionnaire asked teachers to rate how involved each child's parents/carers were in activities taking place at the school (such as parents' evenings, school fetes and concerts) on a 4-point scale ('strongly involved, moderately involved', 'slightly involved' or 'not involved at all').

- Child characteristics (SEN)
- Child's behaviour during the direct assessment (ability to stay on task and the extent to which they were distracted)
- Child's ability to be persistent (teacher-rated)
- Parental involvement with activities at their child's school (teacher-rated)
- Frequency with which the child is take to special or paid activity outside of the home each week.

It is rare to have a model that explains over 70% of the variation in an attainment outcome and this is normally only achieved with a reliable measure of prior attainment. Models that explain below 50% are quite normal and ultimately show that there are other factors, that have not been measured, that explain more of the variation in the outcome of interest. These other factors could be many in number given the variety of possible influences on young children's learning outcomes.

The model identified certain child and family characteristics that were associated with fine motor and gross development at the 5 per cent significance level ($p < 0.05$) after accounting for the influence of other variables included in the model. These are summarised as protective or risk factors in Table 2 and discussed below.

Table 2 Protective factors and risk factors associated with fine motor skill and gross motor skill development at age 5

Protective factors	Risk factors
Factors which were significant for fine and gross motor skills: • Children who were always or often persistent (compared to children who are never persistent) • Parents who were strongly or moderately involved with activities in their child's school (compared to slightly or not involved at all)	Factors which were significant for fine and gross motor skills: • Children who were distracted to a large extent during the direct assessment (compared to not at all distracted) • Children with an identified SEN
Factors which were significant for fine motor skills only: • Children who were older at the time of assessment (being 6 years 0	Factors which were significant for fine motor skills only: • Children who were not at all on task during the direct assessment

Protective factors	Risk factors
months old compared to 4 years 11 months years old) • Children from backgrounds with a higher parental SES compared to the average (mean) SES.	(compared to on task to a large degree) • Children who were distracted to a large extent during the direct assessment (compared to not really distracted) • Being a boy.

Source: IELS assessment of 2,249 children (fine motor) and 2,197 children (gross motor), age 5, England

Where there were statistically significant age-related differences on IELS measures (that is, where children who were older at the time of the study showed greater development), this was used to calculate the average gain in points for each additional month of age. The estimate of months' difference was, in turn, used to calculate the approximate difference between the scores of two groups (for example girls and boys) [17]. In this way, the analysis has been used to indicate in relative terms how many months ahead, or behind, one group is compared to another[18].

Note that children's age in months was not statistically significantly related to their gross motor skill development. For this reason, it is not possible to calculate the equivalent of the effect size for gross motor development in months. Therefore the estimate of months' difference is only reported for fine motor development.

Which factors predict fine motor skill development?

There are several variables which, based on previous research, would be expected to show a significant relationship with children's fine motor skill development. The IELS data was matched to the NPD to enable a multivariate analysis of the factors which were most strongly related to children's fine motor development by the age of 5.

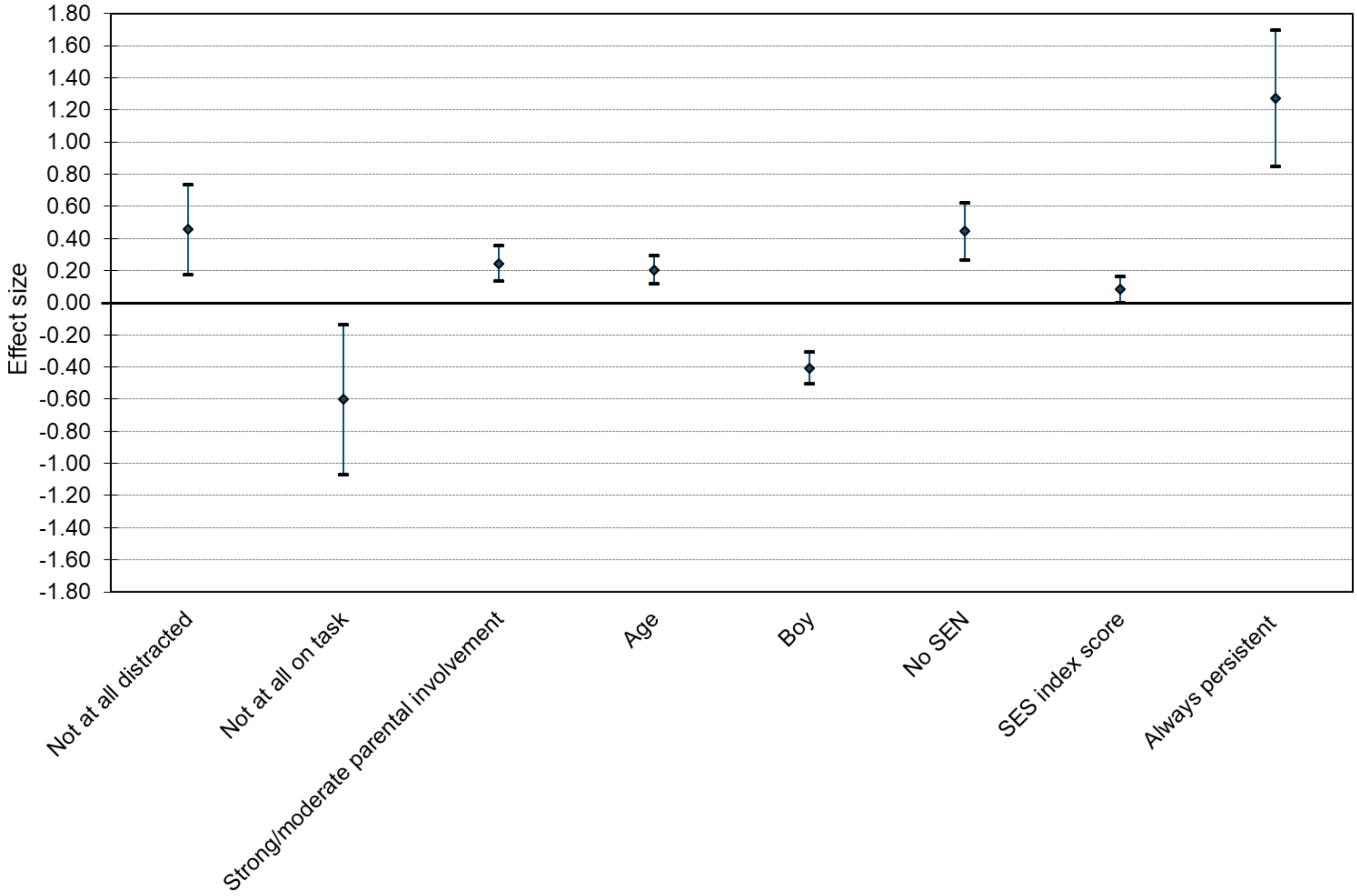
Figure 8 shows the mean effect size[19] of the factors statistically significantly associated with fine motor skill development. Effect size shows the magnitude of a relationship

[17] Please note that the findings have not been age-standardised.
[18] Note that the estimate of the difference by age in months reported here may differ from that reported by the OECD (2020b) because this calculation includes children aged 4 years and 11 months, which were excluded from the OECD's analysis.
[19] This is the absolute effect size between the variable in the model and its comparator.

between two variables in a population, accounting for distribution, and provides a means of comparing between variables using different scales

Where multiple categories for the same variable emerged as significant, the category with the largest effect size is shown. The diamonds depict the mean effect size, while the whiskers above and below the mean show the 95% confidence intervals, taking account of the standard error, meaning that there can be 95% confidence that the true value lies within this range.

Figure 8 Effect size of factors significantly associated with children's fine motor skills



Source: IELS assessment of 2,249 children, age 5, England

Overall, the mean effect sizes ranged from a negative effect for not at all on task during the direct assessment (-0.60) to a strongly positive effect (1.27) for children who were always persistent compared with the children who were never persistent. These findings are discussed below, including the number of months' difference to which the effect sizes equate (in the case of fine motor development).

Fine motor skill development and protective child and family characteristics

The analysis showed that being always or often persistent, having parents who were strongly or moderately involved in their school activities, being older at the time of the study and being from a background with a higher parental SES are associated with higher fine motor development at age 5.

Persistence and fine motor skills

In IELS, teachers were asked to rate each child's persistence, that is, the extent to which the child continued his/her planned course of action in spite of difficulty or obstacles. Among children with a physical development scale score, teachers rated the majority of children as demonstrating persistence sometimes (48%) or often (27%). Only 6% of children were rated as always persistent. Teachers rated 4% of children as never persistent and 15% of children as rarely being persistent.

As indicated in Figure 8, persistence had the largest effect size for fine motor development. The 6% of children who were always persistent were associated with an effect size of 1.27, which is equivalent to a difference of approximately 24 months in fine motor development, compared to the 4% of children who were never persistent. However, being always persistent was associated with larger confidence intervals[20] than other factors – the lower effect size confidence interval is 0.85 and the upper confidence interval is 1.70.

Similarly, the 27% of children who were often persistent had an effect size of 0.71, equivalent to a difference of 14 months compared to the 4% who were never persistent (see Appendix C). This appears to be a new finding identifying a relationship between persistence and children's physical development, although as mentioned above, it is possible that the relationship between fine motor skill development and persistence is underpinned by executive function. Vitiello and others (2011) found that cognitive flexibility (a component of executive function) was related to the child's ability to persist, which was, in turn, related to their ability to learn in school.

Parental involvement with school activities and fine motor skills

Teachers were asked to rate how involved each child's parents/carers were in activities taking place at the school, such as parents' evenings, school fetes and concerts. Among children with a physical development scale score, teachers rated 70% of the children's parents as being moderately or strongly involved in their children's school activities and

[20]The confidence interval represents the range of values within which we can be 95% confident the true mean of the population lies.

30% as slightly or not involved at all. There is little existing evidence available as to the relationship between parental involvement with school and children's fine motor skills. In this analysis, the relationship between fine motor skills and parental involvement was significant and had an effect size of 0.25, equivalent to approximately a 5 month difference in fine motor skills.

Age and fine motor skills

Previous research suggests that being older is positively associated with higher physical development outcomes due to maturation. In the initial bivariate analysis (Kettlewell and others, 2020b), the IELS team in England found an age-related trend whereby older children showed greater physical development than younger children. Similarly, the 2018 EYFSP results show that a higher proportion of children who were older in the year group[21] achieved the expected level in physical development (DfE, 2018b).

Children in the IELS sample in England ranged from 4 years 11 months to 6 years and 0 months old at the time of assessment. The sample was split across 2 year groups: Reception and Year 1, with the majority of children in the sample in Year 1 (84%) (Kettlewell and others, 2020b). The IELS age variable devised by the OECD was calculated as the difference between the date of birth and date of assessment. The analysis reported here found that age was statistically significantly related to fine motor skill development. The effect size associated with being older at the time of assessment (for example 6 years and 0 months old compared to 5 years and 0 months old) was 0.20. This is consistent with the existing evidence.

Parental SES and fine motor skills

The parental SES measure devised by the OECD used 3 parent-reported variables to create an index of socio-economic status (SES), namely: household income, parent occupation and parent educational attainment[22]. In the 2018 EYFSP results (DfE, 2018b), fewer children eligible for FSM achieved the expected level in moving and handling (82%) than children who were not eligible for FSM (91%). Similarly, Kettlewell and others (2020b) found that children eligible for FSM were behind their peers in terms of their physical development. Furthermore, McPhillips and Jordan-Black (2007) found that children living in areas of social disadvantage had significant deficits in motor attainment relative to their more advantaged peers.

[21] The EYFSP results are grouped into three age-related categories: autumn born with birthdays in September to December; spring born with birthdays in January to April; and summer born with birthdays in May to August.
[22] Where the education and occupation levels were available for both parents, the highest levels were used for the analysis.

In this analysis, children from backgrounds with a higher parental SES (compared to the mean) are associated with significantly greater fine motor skill development, although the effect size was quite small at 0.08 (equivalent to about 2 months' difference). To give an example of the size of this effect, for the otherwise average 5-year-old child with a fine motor score of 500, having the lowest SES score would lower their fine motor score to 482, whereas having the highest SES score would raise their fine motor score to 511.

Fine motor skill development and child and family risk factors

The analysis identified a number of factors associated with lower fine motor skill development at age 5. As shown in Figure 8, being distracted during the direct assessment and being unable to stay on task, having an identified SEN and being a boy were all found to be associated with statistically significantly lower fine motor skill outcomes. These can be considered risk factors that may be barriers to good fine motor development at age 5.

Distractibility and fine motor skills

IELS study administrators were asked to rate 2 aspects of the child's behaviour during the direct assessments: the extent to which they were distracted and the extent to which they were able to stay on task[23]. The study administrator rated these behaviours on a 4-point scale ('not at all', 'not really', 'to some degree' and 'to a large extent').

The small minority (1%) of children who were not at all on task during the direct assessment had significantly lower fine motor skill outcomes than the 61% of children who were on task to a large extent. This relationship had an effect size of 0.60, which is equivalent to approximately 12 months' difference in fine motor skills. This was largest effect size among the risk factors identified in this model. There was a similar relationship between children's fine motor development and how distractible they were during the task. Distractibility was associated with lower fine motor skill development, with an effect size of 0.46 or a difference of approximately 9 months in fine motor skill development between the 43% of children who were not at all distracted and the 7% who were distracted to a large extent. A significant difference was also found between the 29% of children identified as not really distracted and those who were distracted to a large extent. This relationship had a slightly smaller effect size of 0.38, equivalent to around 7 months (see Appendix C for further details).

The relationship between fine motor skill development and the extent to which a child is distractible or able to stay on task is consistent with existing evidence of a strong

[23] Note that these variables appear to be measuring different aspects of children's behaviour as the correlation between the two was not sufficiently high to indicate that only one of them should be included in the statistical models. Please see Appendix A for further details.

association between children's ability to pay attention and their motor coordination (Kaplan and others, 2002; Piek and others, 2004). Interestingly, there is evidence of comorbidity between children with movement problems and attention problems (Piek and others, 1999; Kaplan and others, 2002). In the context of children with ADHD, the severity of a child's inattention has been found to be a significant predictor of their motor coordination difficulties (Piek and others, 1999).

SEN and fine motor skills

There is clear evidence that having an SEN adversely impacts a child's physical development. In the 2018 EYFSP results, the gap between the percentage of children with and without SEN who achieved at least the expected level of physical development was 42 percentage points (DfE, 2018b), while the IELS national report for England found children with a SEN identified in the NPD were on average over 12 months behind their peers without SEN in physical development (Kettlewell and others, 2020b).

It is important to point out that the definition of SEN includes a wide range of needs. A total of 299 (12%) of 2,463 children in IELS had a SEN identified in the NPD (Kettlewell and others, 2020b). The majority of these children (61% of those who had an identified SEN) had difficulties with communication and interaction (including speech, language and communication difficulties and autistic spectrum disorder). In addition, 14% had difficulties with cognition and learning (moderate learning difficulties and specific learning difficulties); 13% had social, mental and emotional health issues; 4% had sensory and/or physical needs (hearing impairment, visual impairment and physical disability); and 8% had other difficulties or no specialist assessment of the type of need. It is important to note that the IELS sample does not include children with severe disabilities because the children in IELS were enrolled in mainstream schools rather than special schools and any children with a SEN/disability severe enough to prevent them from engaging with the assessments were not invited to participate. Unfortunately, the relatively small number of children with SEN in the IELS sample prevented further analysis to distinguish the relationships between different types of SEN and fine motor skills.

Previous research has found that the relationship between SEN and physical development is not limited to children with physical needs or disabilities. Hartman and others (2010) found that children with intellectual disabilities had impaired motor skills and executive function. Developmental Co-ordination Disorder (DCD, also known as Dyspraxia) interferes with a child's ability to process information which plays a significant role in their physical development (such as their motor coordination) as well as in their cognitive development (Asonitou and others, 2010; The Dyspraxia Foundation, 2016, NHS, 2021). DCD is also often linked to other SEN and thought to affect at least one child in every classroom (The Dyspraxia Foundation, 2016). Similarly, children with ADHD, which is characterised by persistent inattention and/or hyperactivity-impulsivity, are clinically recognised to be at risk of motor difficulties (Piek and others, 1999). In particular, children with ADHD frequently have difficulties with fine motor skills, which may become apparent through poor handwriting. It is thought that these motor difficulties are related to distractibility and impulsiveness and there is a high comorbidity between ADHD and DCD (Piek and others, 1999; 2004). Finally, motor difficulties are prevalent among children with Autistic Spectrum Disorder (ASD), which is characterised by a range of social and communication impairments and repetitive behaviours (Green and others, 2009; Bhat and others 2011). Children with ASD often have particular difficulty with complex movement tasks that require perceptual processing (Bhat and others, 2011) and/or other cognitive demands such as accuracy or an awareness of timing (Green and others, 2009). This is illuminating in the context of this study as the motor skills measured in IELS via the teacher questionnaire have a high cognitive demand in that the movements included in the measure are relatively complex and require control.

This analysis provides further evidence that having an identified SEN is a risk factor for lower fine motor skill development. The relationship between SEN and fine motor development had an effect size of 0.44 which is equivalent to about 9 months' difference in fine motor development. As Macintyre (2009) points out, difficulties with motor skills can be an important indicator of unidentified or unmet needs when considered alongside children's cognitive development.

Gender and fine motor skills

The IELS sample comprised 49% girls and 51% boys. As noted above, previous evidence suggests a complex relationship between physical development and gender. The IELS national report (Kettlewell and others, 2020b) found that girls were approximately 9 months ahead of boys in physical development, based on a bivariate analysis of the relationship between gender and the overall physical development measure. Similarly, the national EYFSP results in 2018 revealed that a higher proportion of girls reached the expected level than boys (94% compared with 85%) on the moving and handling ELG (which combined both fine and gross motor skills) (DfE, 2018b). However, a study by Kokštejn and others (2017) did not detect any significant differences between boys and girls in fine motor skills among children aged 5 and 6 years, although the same study did find that girls aged 3 and 4 years had greater levels of overall physical development and fine motor skill development than boys.

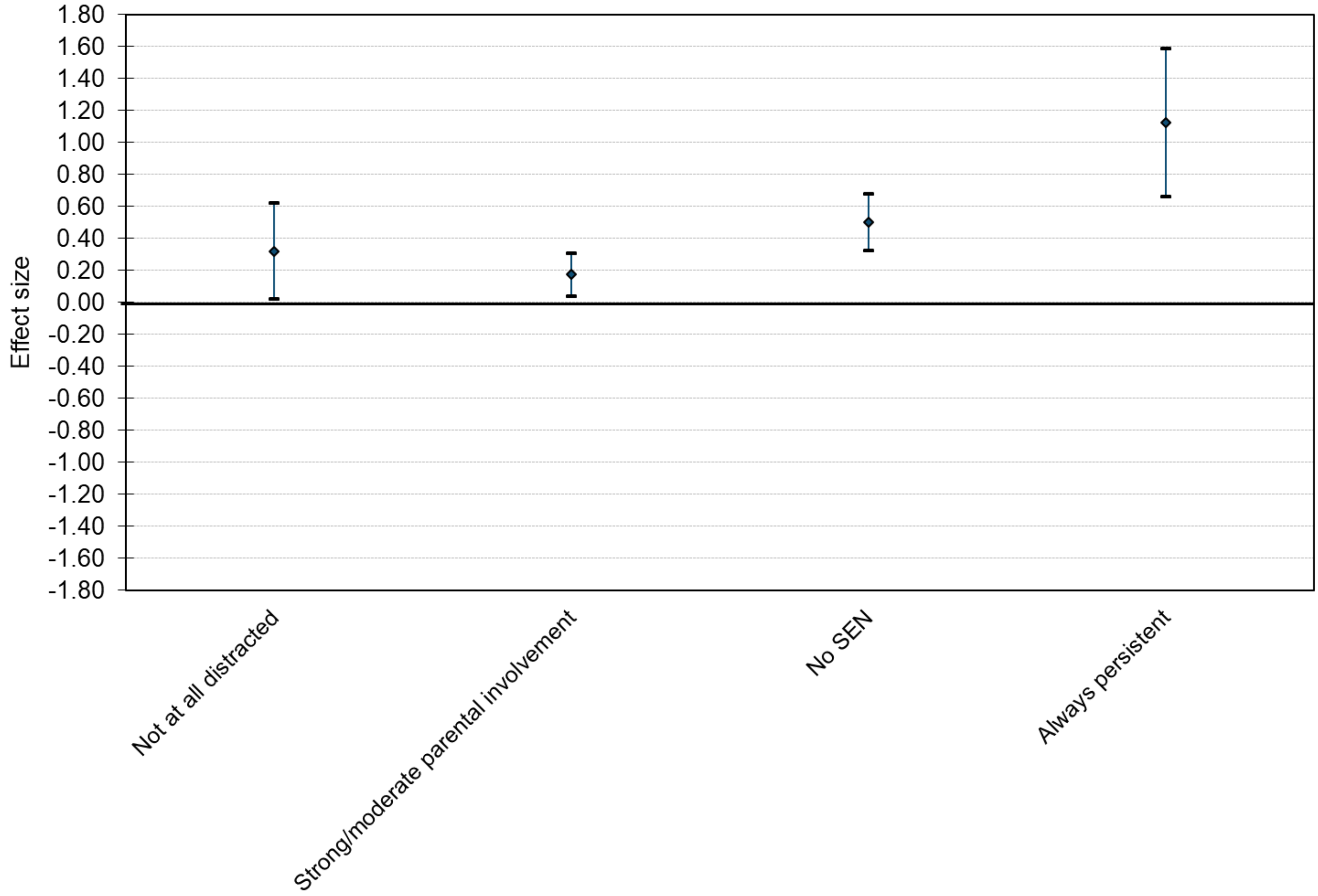
The multivariate analysis shows that boys had a greater risk of lower fine motor skills than girls, with an effect size of 0.41, which is approximately equivalent to 8 months' difference in fine motor development. This is consistent with the EYFSP results and the bivariate analysis from the national report.

Which factors predict gross motor skill development?

Turning to gross motor skill development, existing evidence suggests that several variables might be expected to have a significant relationship with children's gross motor skill development. Once again, the IELS data was matched to the NPD in order to facilitate analysis investigating which factors were most strongly related to children's gross motor development by the age of 5.

Figure 9 shows the mean effect size of the factors statistically significantly associated with gross motor skill development. As explained previously, where multiple categories for the same variable emerged as significant, the category with the largest effect size is shown.

Figure 9 Effect size of factors significantly associated with children's gross motor skills



Source: IELS assessment of 2,197 children, age 5, England

Overall, the mean effect sizes ranged from a relatively small positive effect (0.17) for parents being strongly/moderately involved in their child's school activities compared with slightly/not involved at all to a strongly positive effect (1.12) for being always persistent compared with never persistent. These findings are discussed below. Age was not significantly related to gross motor skill development and so it is not possible to report the effect size in terms of months' difference.

Gross motor skill development and protective child and family characteristics

The analysis found that broadly similar protective factors support stronger gross motor skill outcomes at age 5 as those that support fine motor skill development.

As shown in Figure 9, being always persistent compared to never persistent was associated with a large effect size of 1.12 for gross motor development. However, being always persistent was associated with larger confidence intervals than other factors – the lower confidence interval is 0.66 and the upper confidence interval is 1.59. There was also a significant relationship between being often persistent and never persistent with an effect size of 0.58 for gross motor development (see Appendix C). As discussed above, this aligns with existing literature.

It is possible that the relationship between persistence and gross motor skill development is mediated, at least in part, by the child's executive function. Cognitive flexibility is a component of executive function which has been found to be related to a child's ability to be persistent (Vitiello and others, 2011).

The model also identified parental involvement in activities at their child' school as significant protective factor for gross motor skill development, with an effect size of 0.17, although this relationship had a much smaller positive effect than persistence.

Gross motor skill development and child and family risk characteristics

The model identified 2 risk factors associated with lower gross motor skill outcomes: having an identified SEN and being distractible. These were also identified as risk factors for fine motor development.

The relationship between SEN and gross motor skill outcomes was associated with an effect size of 0.50. This reinforces the importance of identifying children with SEN in order to support all aspects of their motor skill development. The effect size associated with distractibility and gross motor development were of a smaller magnitude (0.32). Once again, these findings are consistent with previous research indicating a strong relationship between attention difficulties and motor difficulties (Kaplan and others, 2002; Piek and others, 2004).

One of the factors identified as a risk for fine motor development was not identified as a risk factor for gross motor development: being a boy was significant in the model for fine motor development but not significant in the model for gross motor development. It therefore seems likely that gross and fine motor skills have different associations with gender.

Which variables would be expected to relate to physical development but were not found in this analysis?

There are several variables which, based on previous research, would be expected to show a significant relationship with children's physical development, but which were not identified as being statistically significantly associated with fine or gross motor skill development in the models reported here. These are discussed below.

Low birthweight

Previous research has suggested that children's physical growth and motor skills may be adversely affected by low birthweight (Burns and others, 2004; Quigley and others, 2012; Zwicker and Harris, 2013). In the IELS sample a total of 177 (11%) children had a low birthweight (defined as less than 2.5kg[24]), out of the 1,580 children who had both responses from their parents about their birthweight and data from their teachers about their physical development. In the initial bivariate analysis (Kettlewell and others, 2020b), the IELS team found a statistically significant difference in the physical development of children in England who had experienced low birthweight and those that had not. Children who had experienced low birthweight had physical development levels equivalent to approximately 9 months lower than their peers.

In the multivariate analysis reported here, low birthweight did not emerge as associated with either fine or gross motor skill development. However, it is worth noting that low birthweight was particularly hard to impute with accuracy, in comparison to the other variables from the parent questionnaire. It could be that this is driving the absence of low birthweight as a risk factor, but further investigation would be needed to establish this with certainty.

The discrepancy between the findings in this analysis and other evidence may also be because previous research considered physical skill development in its entirety and did not consider fine and gross motor skill development separately. Furthermore, it may be due to differences in the measurement of low birthweight and physical development (both were measured indirectly in IELS) and the use of multi-level multivariate analysis in this report, rather than bivariate analysis. In other words, low birthweight may be a useful early indicator that a child may have issues with their physical development, but this

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[24] Equivalent to 5 pounds 8 ounces

analysis suggests that other variables, such as SEN and distractibility are more powerful indicators than low birthweight of poor physical development by the age of 5.

The home learning environment (HLE)

IELS measured the HLE by asking a series of questions in the parent questionnaire about the frequency with which parents carried out activities with their children at home, such as drawing pictures, imaginative play, having back-and-forth conversations, visiting a library and helping their child learn letters of the alphabet. In England, a national question was added to the list of activities which asked parents how often they ‘do activities with your child that help them to learn to read words or sentences’. This was in addition to the international question on doing activities to help children to learn letters of the alphabet. The rationale for adding this item was that, at the time of the study, the majority of 5-year-olds in England had already been in school for over a year and as such were likely to be learning to read words and sentences.

The literature suggests that parenting style, the motor development of immediate family members such as parents and siblings, and parental practices that encourage children to engage in physical activities have positive associations with young children’s physical activity levels (Venetsanou and Kambas, 2010; Davids and Romans, 2014), which is, in turn, is associated with improved motor skills (Cliff and others, 2009; Bürgi and others, 2011). In the bivariate national analysis of IELS (Kettlewell and others, 2020b), children who drew or painted at home 3-4 day per week and children who were taken to special or paid activities outside of the home between 1 and 4 days a week had significantly higher physical development outcomes than children who did these activities less than once a week or never. It also found that children who had more than 100 children’s books in the home showed significantly greater physical development than children with 10 or fewer children’s books.

In contrast to the existing evidence base, no factors related to the child’s HLE were found to be statistically significantly related to fine or gross motor skill development in the final multivariate models. This discrepancy may be a consequence of the aspects of the HLE that IELS measured. IELS measured broader aspects of the HLE that did not necessarily have such a strong physical component to them, whereas the literature suggests that it is family practices in relation to physical activity and the motor development of close family members that influence children’s motor skill development (Cliff and others, 2009; Venetsanou and Kambas, 2010; Bürgi and others, 2011; Davids and Romans, 2014).

A closer look at these findings also suggests that the HLE variables may have not emerged as significant in the multi-level analysis because they are related to child and family characteristics that are already included in the model. For example, having an identified SEN is significantly (and negatively) related to the number of children’s books in the home.

ECEC experience

In England, some 2-year-olds, and all 3-, and 4-year-olds, are entitled to free part-time early childhood education and care (ECEC). At the age of 2, children from disadvantaged backgrounds are eligible for 15 hours of free ECEC per week[25]. At the age of 3, all children are eligible for 15 hours of free ECEC per week. Beyond this, 3- and 4-year olds may then be eligible for extended ECEC provision, which amounts to 30 hours of provision per week[26].

There is mixed evidence on the relationship between physical development and attendance at ECEC. In the national report (Kettlewell and others, 2020b), no significant relationships were detected between physical development and ECEC. This remained the case in this modelling – ECEC was not statistically significantly related to either fine or gross motor skill development. It is likely that this is due to the aspects of ECEC provision measured in the study. IELS primarily measured structural factors such as type of setting and intensity of attendance, whereas the literature suggests the quality of early years settings' provision for facilitating physical development (such as the equipment children can access and the interventions or pedagogical approaches) is more influential (Venetsanou and Kambas, 2010; Shuey and Kanakaras, 2018). It is also important to note that the uptake of free early education entitlement is related to child and family characteristics such as deprivation, EAL, SEN, population mobility and the age of the child (Albakri and others, 2018), which may explain why ECEC was not significant in the multi-level models that included parental SES, SEN and age.

[25] This applies for 38 weeks per year.
[26] This applies to the children of parents working the equivalent of 16 hours a week at the national minimum or living wage and earning under £100,000 per year.

3. Is physical development predictive of other early learning outcomes at age 5?

Chapter summary

This chapter investigates whether children's fine and gross motor development predict children's outcomes in emergent numeracy, emergent literacy, emotion identification and mental flexibility, after taking account for the influence of other variables included in the models.

- Fine motor development was significantly associated with each of the 4 learning outcomes. The effect sizes ranged from 0.44 for emergent numeracy, 0.34 for emergent literacy, 0.26 for emotion identification and 0.24 for mental flexibility.
- Gross motor development was significantly associated with each of the 4 learning outcomes. The effect sizes range from 0.29 for emergent numeracy, 0.24 for emergent literacy, 0.21 for mental flexibility and 0.15 for emotion identification.
- These findings support the growing evidence that children's physical development is positively related to other areas of learning.
- Executive function may play an important role in mediating the relationships between children's physical development and other outcomes.

Overview of the early learning outcomes

This analysis used linear multi-level modelling to examine the association between fine and gross motor skill development and 4 other early learning outcomes (emergent numeracy, emergent literacy, mental flexibility and emotion identification). All of these early learning outcomes were measured directly in IELS via tablet-based activities.

In IELS, emergent numeracy and emergent literacy represent 2 of the 4 core domains measured in the study (OECD, 2020b). Emergent numeracy measured children's ability to recognise numbers and to undertake numerical operations and reasoning in mathematics. The measure focused on simple problem-solving and application of key concepts such as numbers and counting, working with numbers, shape and space, measurement, and pattern. For emergent literacy, 3 areas were measured: listening comprehension, vocabulary knowledge and phonological awareness. Note that as IELS is an international assessment, reading and writing were not assessed, as many countries do not teach reading until after age 5. The assessment focused on pre-reading literacy and language skills that are predictive of later reading success (Shuey and Kankaras, 2018) and differs from the expectations of the EYFS in England.

Mental flexibility is one of 3 components within the self-regulation domain. The task measures the child's ability to shift between rules according to changing circumstances or to apply different rules in different settings. Emotion identification is one of 5 aspects of children's social-emotional development measured in IELS. The assessment asked children to respond to story-based scenarios and measured whether children were able to empathise with the characters by correctly identifying the characters' emotional state.

In the analysis conducted for the national report (Kettlewell and others, 2020b), each of these early learning outcomes had a moderately strong correlation[27] with the overall measure of physical development.

Overview of the statistical models

Once again, linear multi-level modelling was used to examine the association between different variables and each of the 4 learning outcomes. For each learning outcome, separate models were run – one incorporating fine motor skills as an independent variable and one incorporating gross motor skills as an independent variable. It was necessary to run separate models for fine and gross motor skills because these samples were based on different numbers of children. A large number of variables were tested in the modelling. To be included in the final model, the variable had to be significantly related to the dependent variable individually and then had to improve the predictive ability of the multi-level model over and above the other variables in the model (see Appendix A for further details of the methodology and Appendix C for details of all the variables tested for inclusion in the models).

The final 8 models included the following variables[28].

- Fine or gross motor skill outcomes
- Child characteristics (age, gender, FSM eligibility, year group, SEN and EAL)
- Family characteristics (parental SES and parental involvement in school activities as rated by teachers)
- Child's ability to be persistent (rated by teachers)

[27] A correlation lower than 0.20 is considered relatively weak, between 0.20 and 0.50 is moderately strong, and over 0.50 is strong.
[28] Each of the 8 final models contained a slightly different selection of these variables, based on the statistical significance of their relationship with the learning outcome in question and whether they added to the predictive ability of the final model.

- Child's distractibility and on-task behaviour during the direct assessment ('Was the child easily distracted?' and 'Did the child stay on task?', as rated by the study administrators)
- HLE factors (number of children's books in the home, frequency of reading words and sentences, frequency with which child uses a device and frequency with which child is taken to a special or paid activity outside of the home, frequency with which they have a back-and-forth conversation about how they feel and why they feel that way). These variables were taken from the parent questionnaire.
- School-level deprivation (IDACI).

Table 3 shows the proportion of the variance explained for each of the learning outcome models. There is a degree of consistency in that the models explain more variation for emergent numeracy and emergent literacy than they do for emotion identification and mental flexibility. This was also true for the thematic analysis using IELS data to explore the influence of deprivation on children's outcomes (see Classick and others, 2021).

Table 3 Variation explained for each of the learning outcome models

Learning outcomes	Model including fine motor variable	Model including gross motor variable
Emergent numeracy	49%	46%
Emergent literacy	46%	44%
Emotion identification	28%	27%
Mental flexibility	25%	26%

Source: IELS assessment of 2,302 children, age 5, England

As explained previously, it is rare for a model to explain over 70% of the variation in an attainment outcome and this is normally only achieved with a reliable measure of prior attainment. Models that explain below 50% are quite normal and ultimately show that there are other factors, that were not measured, that explain more of the variation in the outcome of interest.

Is fine motor skill development predictive of other early learning outcomes at age 5?

The analysis found that fine motor skills were statistically significantly associated with higher scores in each of the 4 other learning outcomes. The effect size associated with these relationships[29] are shown in Table 4.

Table 4 Effect size associated with fine motor skills and other learning outcomes

Learning outcomes	Fine motor skill effect size
Emergent numeracy	0.44
Emergent literacy	0.34
Emotion identification	0.26
Mental flexibility	0.24

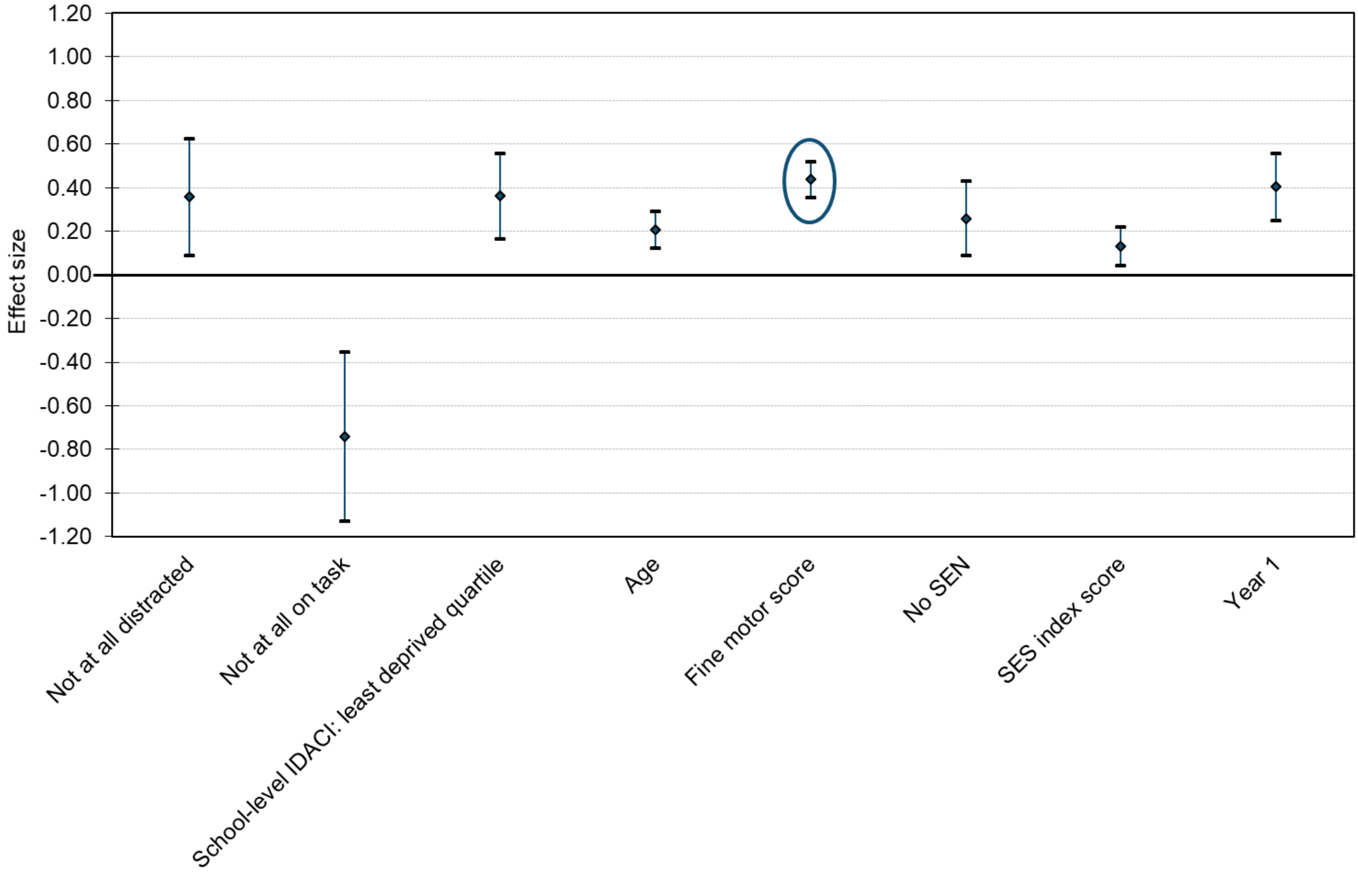
Source: IELS assessment of 2,249 children, age 5, England

Multiple protective factors were common to more than one of the 4 learning outcomes, including: being in Year 1, being older at the time of assessment[30] and being from a background with a higher parental SES. Risk factors common to more than one of the other learning outcomes include: being distracted, not staying on task, having an identified SEN and attending a school in most deprived school IDACI quartile.

Figures 10, 11, 12 and 13 show the effect size of the factors statistically significantly associated with emergent numeracy, emergent literacy, mental flexibility and emotion identification with fine motor scores included as an independent variable. Once again, where multiple categories for the same variable have emerged as significant, the category with the largest effect size has been shown in the figures (full details of all the relationships are available in Appendix C).

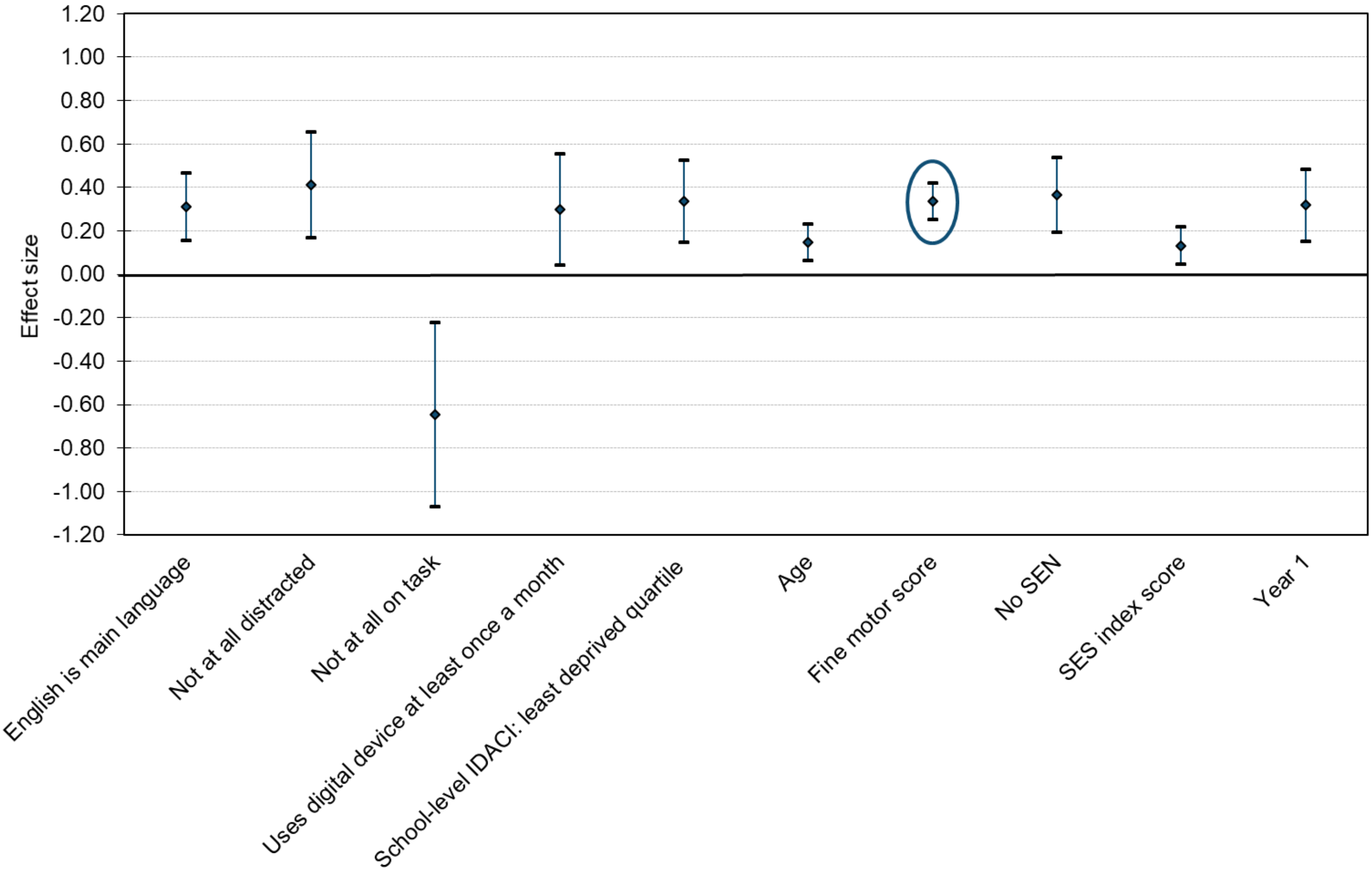
[29] As fine and gross motor development are continuous variables, the effect size calculated represents the effect of a change in the independent variable (that is, fine motor score or gross motor score) equivalent to its adjusted standard deviation on the outcome of interest.
[30] Note that while children's age and year group are related, the correlation between the two was not sufficiently high to indicate that only one of them should be included in the statistical models. Please see Appendix A for further details.

Figure 10 The effect size of factors significantly associated with emergent numeracy, including fine motor skills



Source: IELS assessment of 2,249 children, age 5, England

Figure 11 The effect size of factors significantly associated with emergent literacy, including fine motor skills



Source: IELS assessment of 2,249 children, age 5, England

As shown in Figure 10, fine motor skills were statistically significantly associated with emergent numeracy with an effect size of 0.44 (which is equivalent to a difference of about 4 months). Fine motor skills were also significantly related to children's emergent literacy with an effect size of 0.34 (which is equivalent to about 5 months' difference).

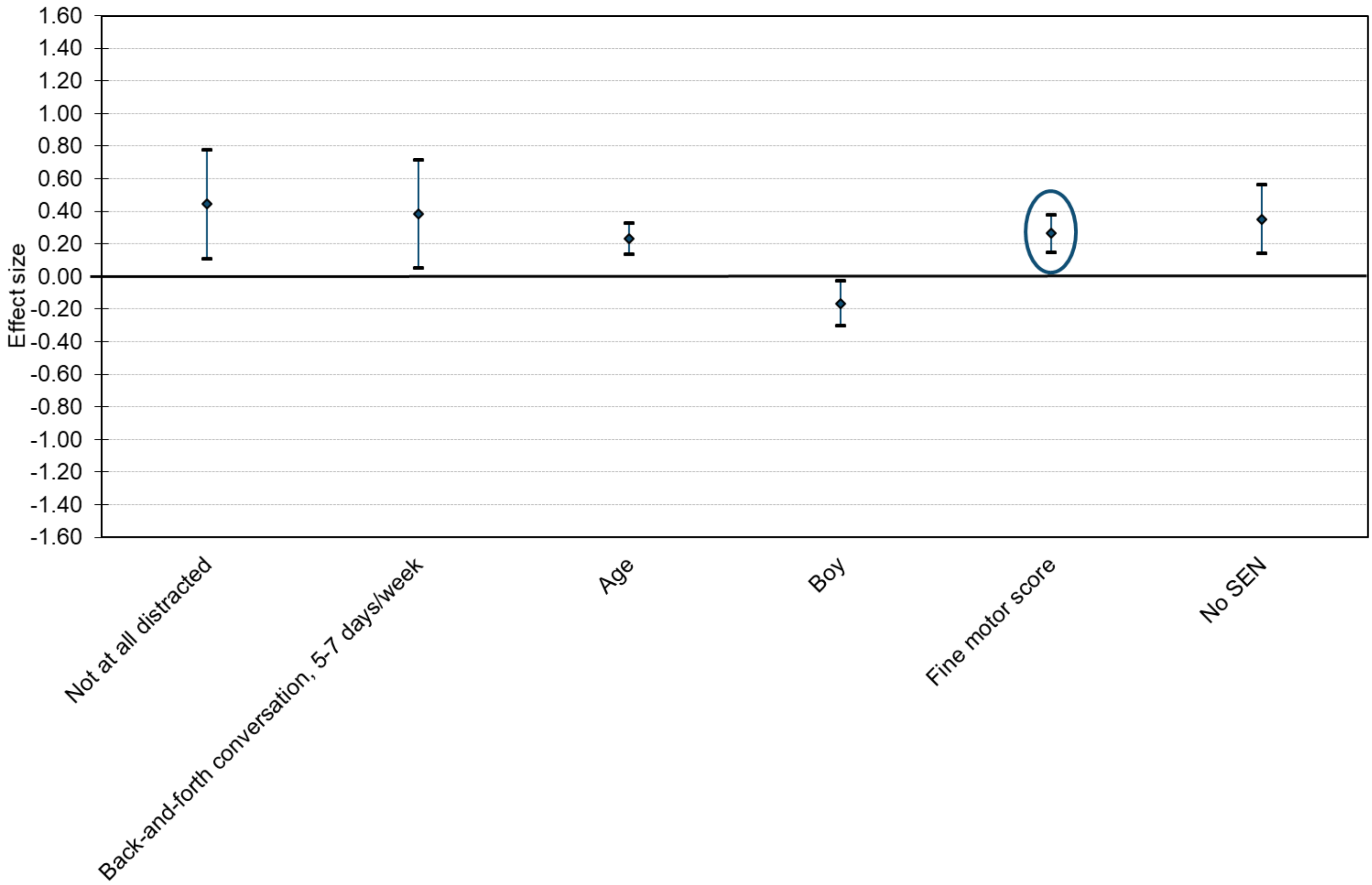
In the emergent numeracy model, fine motor skills had the second largest effect size following not at all being on task during the direct assessment (compared to being on task to a large extent) which had the largest effect size (0.74). In the emergent literacy model, fine motor skills emerged as one of a group of variables with effect sizes of a similar magnitude, including: being in Year 1 rather than Reception (0.32), not having an identified SEN (0.37) and attending a school in the least deprived IDACI quartile compared to the most deprived IDACI quartile (0.34).

This supports the growing evidence that fine motor skill development is an important predictor of early numeracy and early language/literacy outcomes (Timmons and others, 2007; Le Fevre and others, 2010; Dinehart and Manfra, 2013; Pitchford and others, 2016; Asmussen and others, 2018; Suggate and others, 2019; Macdonald and others, 2020; Michel and others, 2020).

Asmussen and others (2018) identify early fine motor development as one of 3 particularly important competencies, alongside verbal ability and executive function, for improving children's early numeracy skills. Evidence also suggests that the relationship between fine motor skill development and mathematical ability can be observed among older primary-aged children (Grissmer and others, 2010). There is conflicting evidence, however, as to whether the relationship between fine motor skills and emergent numeracy is mediated by executive function (Le Fevre and others, 2010; Asmussen and others, 2018; Michel and others, 2020).

Regarding the relationship between fine motor skills and emergent literacy, there is some evidence that this relationship may be driven by verbal short-term memory, that is, a child's ability to recall information given to them orally (and therefore related to executive function), rather than by fine motor development alone (Pitchford and others, 2016). Further evidence is needed to understand the role of executive function in the relationship between fine motor skills and emergent literacy. There is evidence that fine motor skills are strong predictors of reading outcomes in older primary-aged children (Grissmer and others, 2010).

Figure 12 The effect size of factors significantly associated with emotion identification, including fine motor skills

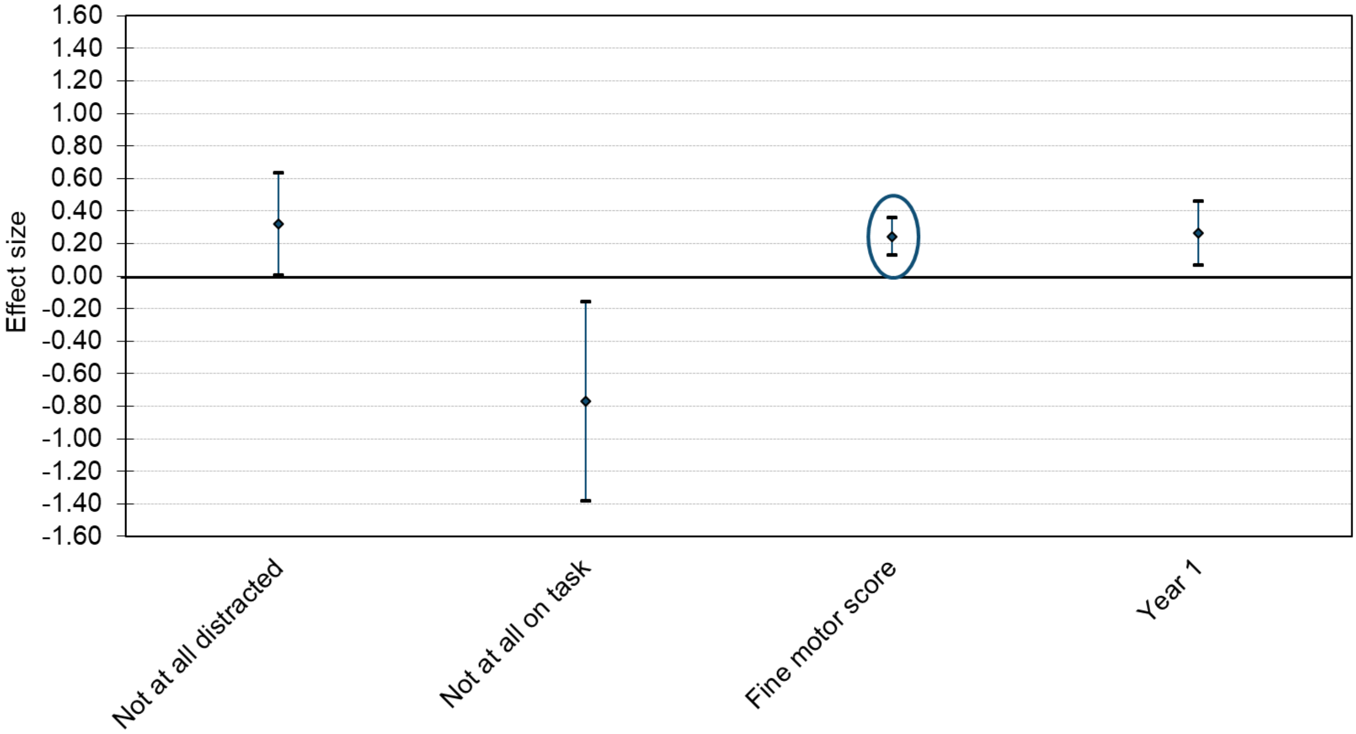


Source: IELS assessment of 2,249 children, age 5, England

As shown in Figure 12, the relationship between fine motor skills and emotion identification has an effect size of 0.26, equivalent to a difference of about 4 months. In comparison to the other statistically significant variables that emerged in this model, fine motor skills had quite a small effect size – only being a boy and being younger have smaller effect sizes (0.17 and 0.23 respectively).

There is little existing research evidence about the relationship between fine motor skills and emotion identification, or indeed social-emotional skills more generally. However, motor skill development is known to be important for enabling children to participate in cognitive and non-cognitive learning opportunities, including play (Macintyre, 2009). Similarly, Kaplan and others (2002) found that children with motor difficulties were at risk of difficulties with social and peer relationships. Evidence also suggests that peer play is an important mechanism through which physical and social-emotional development can take place (UNICEF, 2018). Mathieson and Banerjee (2010) suggest that social-emotional learning is facilitated through peer play as children learn to manage their emotions, behaviours, and relationships with others. Similarly, executive function has also been found to be significantly positively associated with cognitive empathy (Yan and others, 2019). As such, it may be that the relationship between fine motor skills and emotion identification found in this analysis is mediated by executive function and socialisation through play. Further work is needed to clarify these relationships.

Figure 13 The effect size of factors significantly associated with mental flexibility, including fine motor skills



Source: IELS assessment of 2,249 children, age 5, England

As shown in Figure 13, there was a significant relationship between fine motor skills and mental flexibility with an effect size of 0.24 (equivalent to about 4 months' difference). This is the smallest effect size of all the variables that emerged as statistically significantly related to mental flexibility and is similar in magnitude to the effect size of being in Year 1 rather than Reception (0.26).

There is very little existing evidence on the relationship between motor skills and mental flexibility. However, mental flexibility (often referred to as 'cognitive flexibility') is part of executive function (Jacques and Zelazo, 2005) and, as noted above, there is emerging evidence of a relationship between executive function and children's fine motor skills (Van der Fels and others, 2015; Michel and others, 2020). Further research is needed to understand more about the relationship between fine motor skills and executive function.

Is gross motor skill development predictive of other early learning outcomes at age 5?

This analysis found that gross motor skill outcomes were statistically significantly associated with higher scores in each of the 4 other learning outcomes. The effect size associated with these relationships are shown in Table 5.

Table 5 Effect size associated with gross motor skills and other learning outcomes

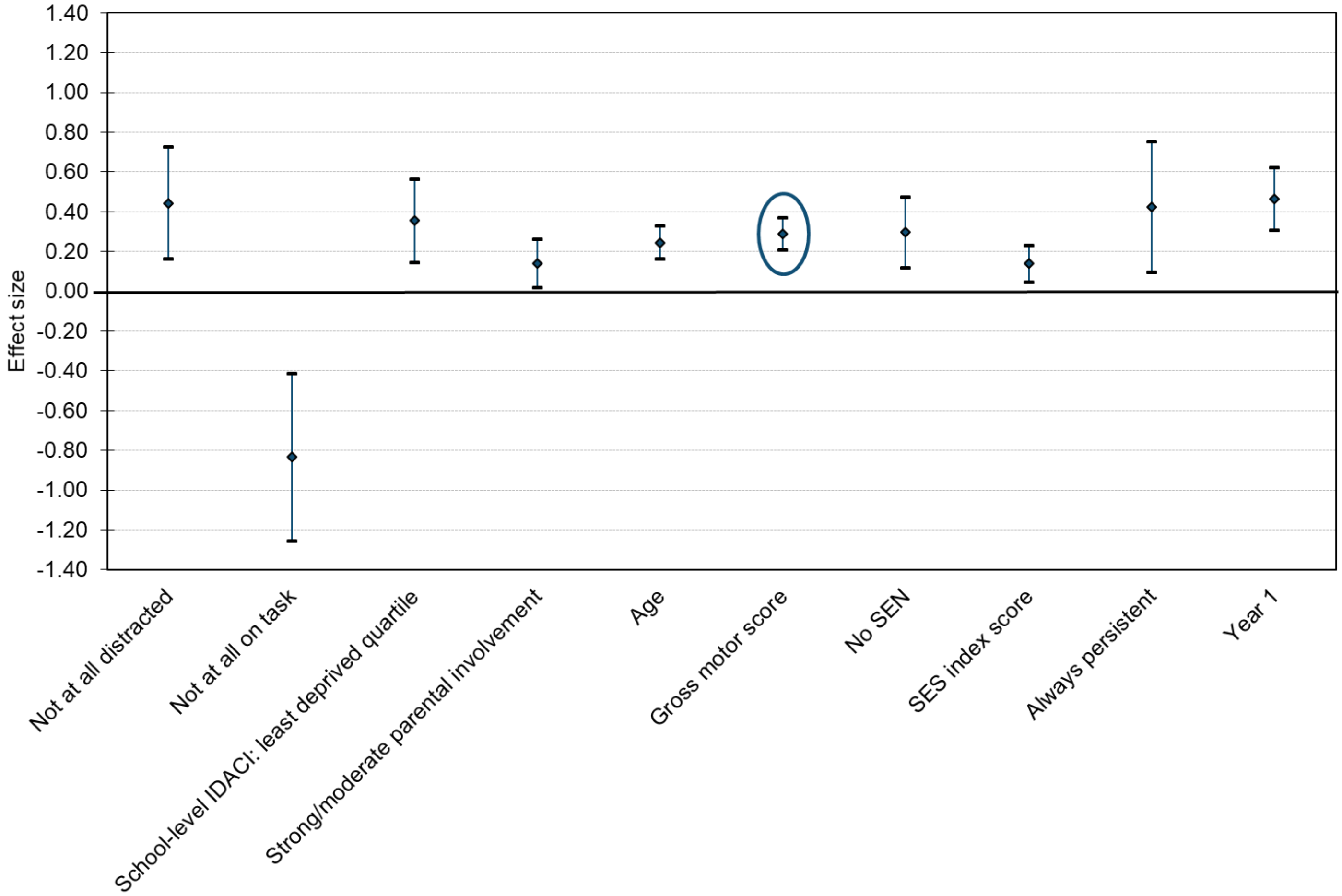
Learning outcomes	Gross motor skill effect size
Emergent numeracy	0.29
Emergent literacy	0.24
Mental flexibility	0.21
Emotion identification	0.15

Source: IELS assessment of 2,197 children, age 5, England

Overall, the factors associated with emergent numeracy, emergent literacy, mental flexibility and emotion identification are similar across the models including fine and gross motor skills, with only a few additional factors present in the models including gross motor skills. Multiple protective factors were common to more than one of these 4 learning outcomes in addition to gross motor skills. These include: being in Year 1, being older, being from a background with a higher parental SES and having parents strongly or moderately involved in school activities. There were also a number of risk factors common to more than one of these learning outcomes: being distracted, not staying on task, having an identified SEN and attending a school with high levels of deprivation. For the full models, see Appendix C.

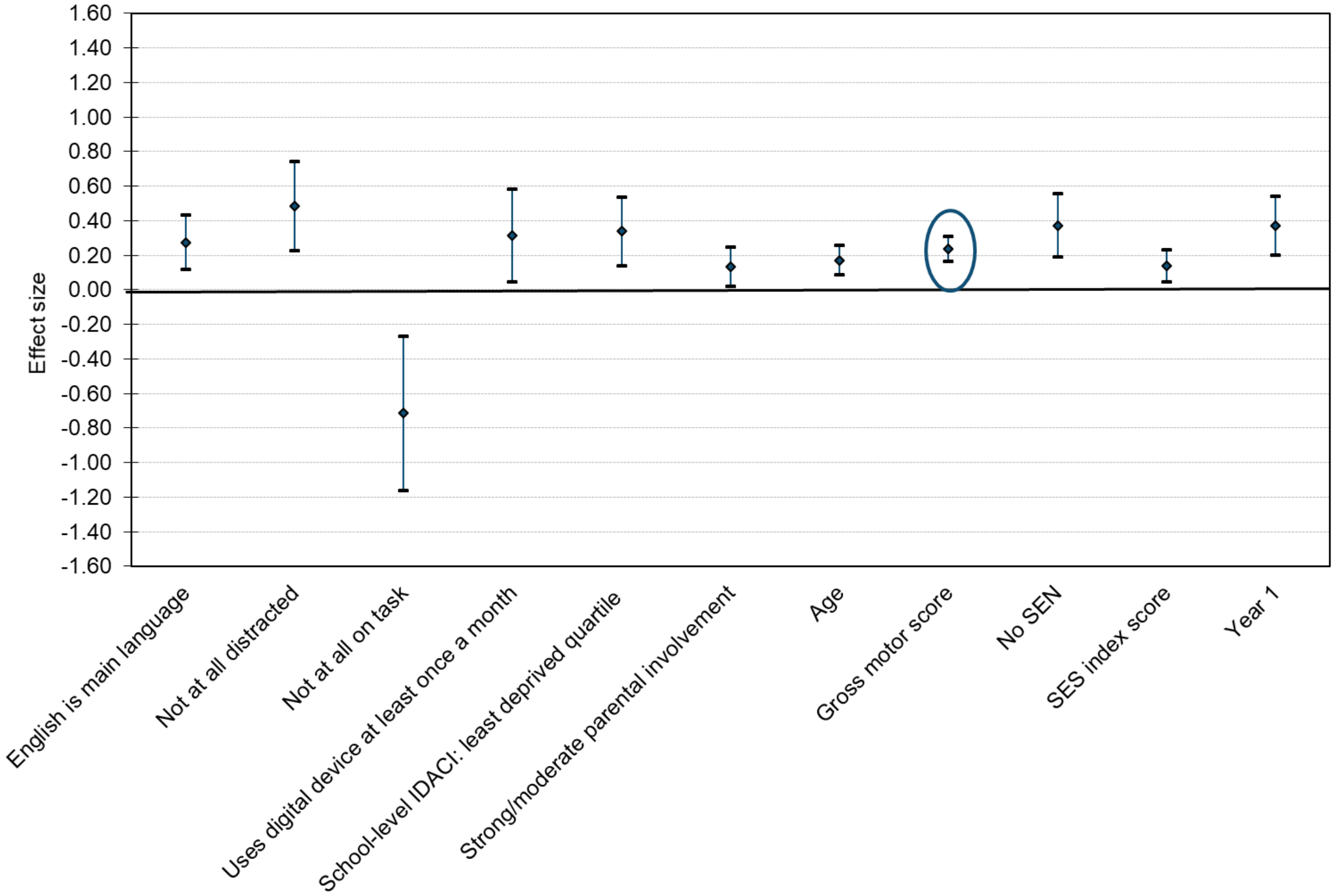
Figures 14, 15, 16 and 17 show the effect size of the factors statistically significantly associated with emergent numeracy, emergent literacy, mental flexibility and emotion identification with gross motor scores included as an independent variable. As has previously been noted, where multiple categories for the same variable have emerged as significant, the category with the largest effect size has been shown.

Figure 14 The effect size of factors significantly associated with emergent numeracy, including gross motor skills



Source: IELS assessment of 2,197 children, age 5, England

Figure 15 The effect size of factors significantly associated with emergent literacy, including gross motor skills

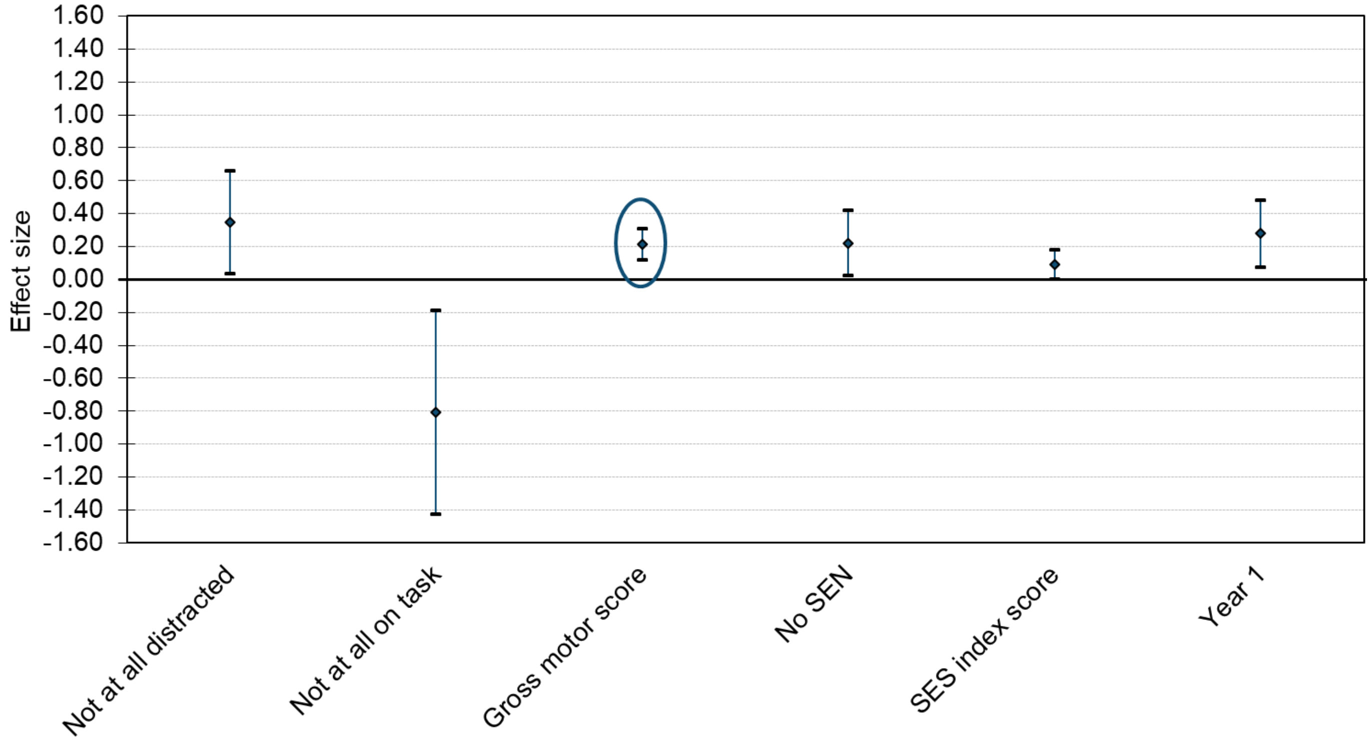


Source: IELS assessment of 2,197 children, age 5, England

As was the case for fine motor skills, gross motor skills was associated with emergent numeracy and emergent literacy, with effect sizes of comparable magnitudes (0.29 and 0.24) as shown in Figures 14 and 15. For both emergent numeracy and emergent literacy, this is equivalent to a difference of approximately 3 months. Gross motor skills had comparatively small effect sizes for the relationship with emergent numeracy and emergent literacy. Within the emergent numeracy model, the gross motor skills effect size was similar to being older at the time of the study (0.25) and having an identified SEN (0.30). In the emergent literacy model, the effect size for gross motor skills was comparable with having EAL (0.27). Most of the literature focuses on the relationship between numeracy and fine motor skills, although Macdonald and others (2020) found that Year 1 children's overall motor skills were significantly associated with their early mathematical skills. There is very little research exploring the association between gross motor skills and numeracy outcomes. Similarly, there is a lack of literature investigating the relationship between gross motor skills and emergent literacy – most of the available evidence explores physical development overall or focuses specifically on children's fine motor skills.

Figure 16 shows the relationship between mental flexibility and gross motor skills.

Figure 16 The effect size of factors significantly associated with mental flexibility, including gross motor skills

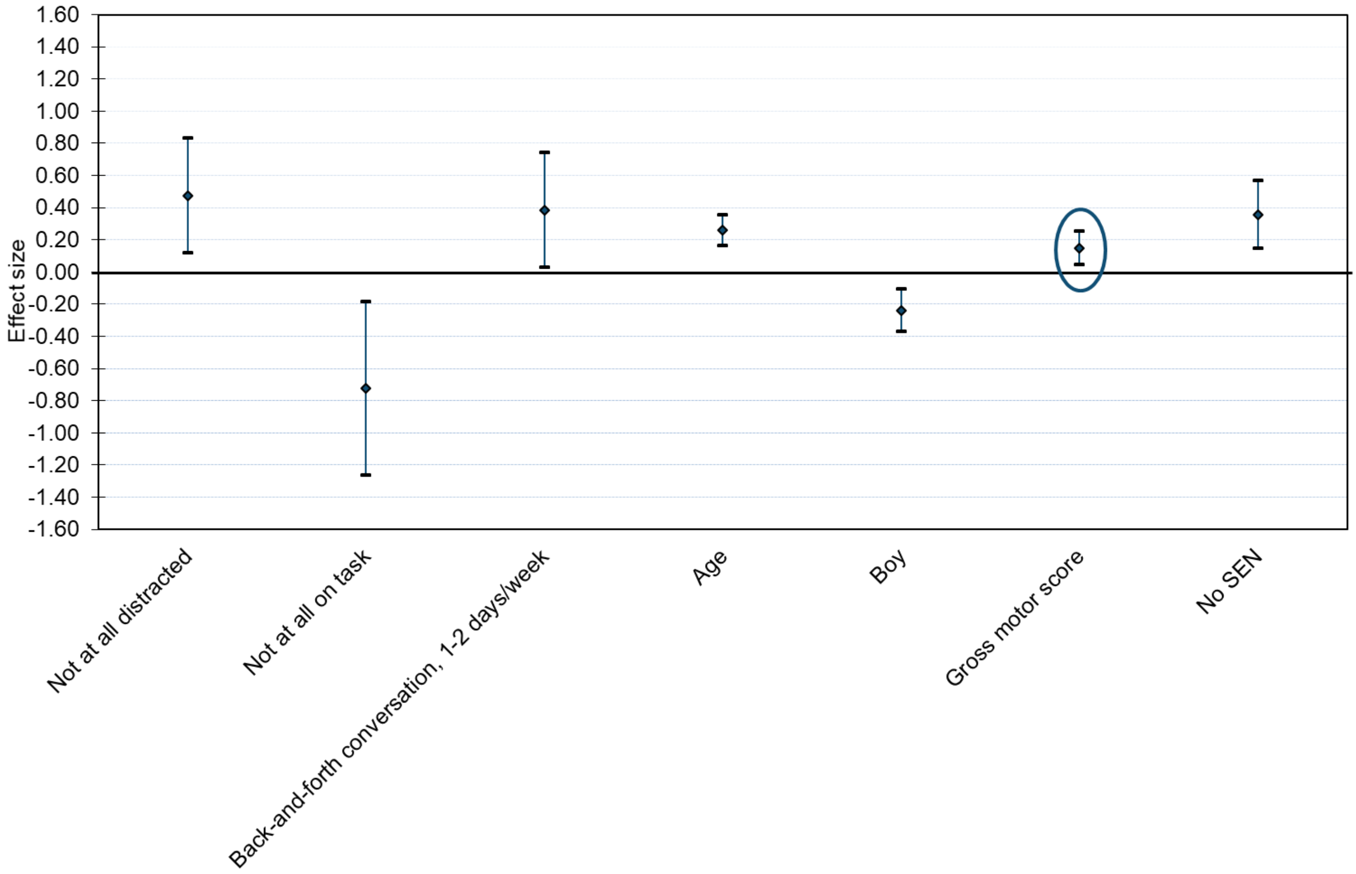


Source: IELS assessment of 2,197 children, age 5, England

Gross motor development was significantly associated with mental flexibility, with an effect size of 0.21. This is one of the smallest effect sizes of any of the factors associated with mental flexibility – only parental SES had a smaller effect size – yet it is equivalent to about 4 months of development in mental flexibility. As previously discussed, there is little evidence relating to the relationship between young children's gross motor skills and mental flexibility. However, it may be that executive function plays a role in mediating this relationship as mental flexibility is part of executive function (Jacques and Zelazo, 2005).

Figure 17 shows the relationship between gross motor skills and emotion identification.

Figure 17 The effect size of factors significantly associated with emotion identification, including gross motor skills



Source: IELS assessment of 2,197 children, age 5, England

Gross motor development was significantly associated with emotion identification. The effect size associated with this relationship (0.15) was the smallest effect size to emerge within this model, equivalent to about 2 months of development. As mentioned above in relation to fine motor skills, there is very little evidence on the relationship between gross motor skills and emotion identification. Further research is needed to establish whether this association is driven by executive function (Yan and others, 2019) and/or is influenced by playing with peers (Mathieson and Banerjee, 2010; UNICEF 2018).

4. Discussion and conclusion

This analysis has demonstrated the importance of physical development in children's early learning and identified key risk and protective factors associated with both fine and gross motor skill development.

Persistence and parental involvement are related to fine and gross motor development

It is important to distinguish between factors that are more malleable and therefore have the potential to be influenced by policy and practice, and those that are more fixed but may be useful as indicators (Gorard and Huat See, 2013). Given that data for the IELS study was collected from participants on a single occasion (i.e. the study used a cross-sectional design), it is not possible to determine whether findings from IELS represent malleable or fixed factors, but it is possible to draw on evidence from other research to understand more about this.

While it may be thought of as a fixed component of personality, there is evidence that persistence may be considered to be a malleable factor that is shaped by the family environment while children are younger, and can also be promoted in educational settings. For example, Leonard and others (2019) found that adults are able to influence children's persistence with their actions, outcomes and words. Persistence also appears related to executive function, which evidence suggests can be influenced through classroom-based pedagogy and specific interventions (Davis and others, 2011; Diamond, 2012; Serpel and Esposito, 2016; Ackerman and Friedman-Kraus, 2017; Schmidt and others, 2017; EEF, 2021). These findings suggest that schools should adopt practices that are proven to increase children's persistence.

There was also evidence that parental involvement in activities at their child's school is a protective factor, so schools should continue to engage and involve parents in school life on the basis that parental involvement is a promising avenue for improving pupil outcomes (Houtenville and Conway, 2008).

Physical development is related to cognitive development

The risk factors for both fine and gross motor development identified in this analysis were having a SEN, being distractible and having difficulty staying on task. This underlines the connections between cognitive and physical development (Piek and others 1999; 2004). Teachers and early years practitioners may find it helpful to be aware of these risk factors to help them monitor and support children's motor development more effectively. Furthermore, this analysis supports previous research suggesting that motor skills are an important indicator, when considered alongside other cognitive outcomes, of unidentified special educational needs. This may be particularly important for children with SEN (and particularly DCD, ADHD, and ASD) because motor skill difficulties are often evident at an earlier age than cognitive indicators (Macintyre, 2009; Bhat and others, 2011). An awareness and understanding of motor skill development, its risk and protective factors, and the relationships between motor skills and other learning outcomes, may help teachers and other early years practitioners intervene earlier to support children with or at risk of having poor motor skills (Green and others, 2009; Asonitou and others, 2010; Venetsanou and Kambas, 2010; Bhat and others, 2011; Macdonald and others, 2020). Policymakers could support schools and ECEC settings by providing guidance on the key protective and risk factors associated with fine and gross motor development.

Schools and ECEC settings have an important role in supporting children's physical development

The Covid-19 pandemic has drawn attention to the importance of school attendance for young children and raised concerns about the impact of periods of 'lockdown' on children's physical development. Ofsted (2020a and 2020b) reported that school leaders and early years practitioners observed a regression in some children's fine and gross motor skills resulting from periods when children were unable to attend school. For example, school leaders reported that some children were now unable to hold a pencil, when they had previously been able to do this successfully (Ofsted, 2020b). YouGov (2020) found that 37% teachers reported over half of Reception children struggled to hold a pencil. Similarly, Bowyer-Crane and others (2021) found that 73% of teachers were concerned about the physical development of young children in their school. Extended periods of remote learning at home appear to have reduced some children's opportunities to practise fine motor skills like using pencils or scissors, while others have had limited access to outdoor space and lost confidence in gross motor skills such as jumping from large-scale equipment (Ofsted, 2020b).

When schools opened to all pupils in September 2020, some schools and early year settings started prioritising opportunities for pupils to practise and develop their motor skills (Ofsted, 2020a; 2020b). Examples included incorporating additional learning activities involving modelling, teaching pencil grip and letter formation, and supporting children to use large playground equipment. However, the subsequent period of remote learning in early 2021 may have had a further negative effect on children's physical development.

While this analysis suggests that structural factors relating to ECEC (such as setting type or attendance) are not related to physical development, the wider evidence suggests that ECEC quality and targeted interventions in schools are important for promoting children's physical development (Venetsanou and Kambas, 2010; Livonen and Sääkslahti 2013).

Physical development can be supported and improved through universal interventions. Given the amount of time children spend in their ECEC and school settings, these are important venues for physical development (Venetsanou and Kambas, 2010) and early intervention programmes have been shown to enhance children's motor development. The evidence highlights the importance of teaching children motor skills deliberately with specific structured steps and adequate equipment, and not solely focusing on providing opportunities for unstructured physical activity – valuable as this may be for children's play and socialisation (Venetsanou and Kambas, 2010). For example, Livonen and Sääkslahti (2013) found that a range of preschool programmes that sought to develop motor skills, lasting over 8 weeks with at least 2 structured sessions per week, improved children's gross motor skills. These interventions appear to have a moderate impact and can be implemented at very low cost (EEF, 2019). While the evidence is clear that physical development interventions can be effective, further research is needed to identify the key components and longer-term efficacy of classroom-based interventions (Eddy and others, 2019; EEF, 2019).

Targeted interventions and pedagogical approaches can be used to support the needs of specific groups of children, particularly children with identified SEN that impact their motor skills (Eddy and others, 2019). For example, the Dyspraxia Foundation (2016) recommend children with DCD can be better supported if they are not given more than two instructions at once and are allowed additional time to complete tasks. There is also some evidence that targeted approaches of this kind can be beneficial to the whole class, not just children with identified SEN. Valentini and others (2016) found that a mastery intervention based on six core pedagogical approaches improved motor skill outcomes for children with and without SEN. These approaches include: providing feedback and encouragement; providing opportunities for decision-making and goal setting; including parents to recognise achievement; creating opportunities for leadership and self-pacing; guiding children using verbal cues and modelling; and teaching children to monitor their own progress. This reinforces the value of specific motor skill instruction in addition to facilitating and encouraging physical activity for developing children's motor skills. Targeted interventions or pedagogical approaches that are planned according to each child's needs can help mitigate the impact of these specific difficulties on children's longer-term outcomes (Venetsanou and Kambas, 2010). Policymakers may wish to promote effective interventions and pedagogical approaches, both universal and targeted, to schools and ECEC settings.

Fine and gross motor skills are related to other key learning outcomes

This thematic report has found that both fine and gross motor skills were statistically significantly related to each of the other 4 learning outcomes selected for investigation: emergent numeracy; emergent literacy; mental flexibility; and emotion identification. While these effect sizes may be relatively small, they support the growing evidence that children's physical development has the potential to benefit other areas of learning. For example, Van der Fels and others (2015) found that motor intervention programs that encourage children to undertake increasingly complex movements as quickly as possible aid the development of cognitive skills as well as motor skills. Similarly, findings from Pitchford and others (2016) suggest fine motor skills are key to supporting the development of early mathematical skills. There is also growing evidence that physical activity is mutually beneficial for motor and cognitive outcomes, including self-regulation and executive function (Bürgi and others, 2011; Carson and others, 2016; Schmidt and others, 2017; EEF, 2019; Vasilopoulos and Ellefson, 2021).

The evidence suggests that physical development warrants attention in its own right as a key area of development in young children that is mutually supportive of other cognitive and non-cognitive areas of development. Incorporating motor skill development and physical activity, including outdoor play, into the broader framework for early years provision may also be beneficial for supporting cognitive outcomes (Timmons and others, 2007). Overall, this supports the inclusion of gross and fine motor development as separate aspects in the EYFS. However, future research is needed to strengthen the evidence base in this area and to identify the most effective approaches (Carson and others, 2016; EEF, 2019). Including children's fine and gross motor development in the EYFSP is also an important mechanism through which policymakers and researchers can monitor children's physical development. Furthermore, policymakers should consider continuing to collect robust evidence on gross and fine motor skills in studies of early childhood development (such as IELS). This would also provide an opportunity to monitor children's physical development and its relationship with other outcomes over time.

Enhancing children's executive function is a promising area for policy and practice

Given the relationship between executive function, physical development and other learning outcomes, consideration should be given to the factors that can enhance children's executive function. Various activities including physical activity, computer-based training and semi-structured peer play appear to improve executive function (Diamond, 2012; Serpel and Esposito, 2016; Ackerman and Friedman-Kraus, 2017). These interventions can be implemented at low cost and children with poor executive function appear to benefit the most (Serpel and Esposito, 2016). Embedding strategies focused on executive function and self-regulation in the early years also appears particularly beneficial for children from deprived backgrounds, who are likely to have weaker self-regulation skills than their peers (EEF, 2021). This evidence aligns well with the evidence, presented above, that demonstrates the importance of physical activity for supporting children's motor skill development and other learning outcomes (Davis and others, 2011). There are also promising indications that improvements in executive function transfer to academic achievement, particularly in maths (Davis and others, 2011;

Harvey and Miller, 2017; Schmitt and others, 2017), as well as non-cognitive outcomes such as persistence and behaviour (EEF, 2021). However, more research is needed to confirm the nature of these relationships and ascertain how long these benefits last (Diamond, 2012; Serpel and Esposito, 2016; Ackerman and Friedman-Kraus, 2017). Policymakers and researchers should consider investigating the role of executive function further to understand how this aspect of cognitive development supports other aspects of children's development and whether executive function should be promoted in ECEC settings and schools.

Conclusions

This research sought to understand the factors that are related to fine and gross motor skills at age 5, and how fine and gross motor skills relate to other early learning outcomes. The variables in the fine motor model accounted for a higher proportion of variance in children's fine motor development (39%) than the variables in the gross motor model did for children's gross motor development (22%). It is likely that fine motor measure was better able to capture children's development because fine motor skills were associated age, whereas gross motor skills were not. The analysis found that broadly similar protective factors support both stronger fine and gross motor skill outcomes at age 5 and broadly similar risk factors hinder children's fine and gross motor skill development. Persistence and strong or moderate parental involvement were found to be significantly related to higher fine and gross motor outcomes, while being from a background with a higher parental SES was only significantly related to fine motor skills. Conversely, having an identified SEN and being distractible were risk factors significantly associated with lower fine and gross motor outcomes, while not being able to remain on task and being a boy were risk factors associated with fine motor outcomes only.

This research has identified 2 fixed risk factors for poor fine motor development in particular: being younger and being a boy. This is important because fine motor development underpins handwriting (Dinehart and Manfra, 2013), which is a key skill for children as they enter Year 1. Children with these characteristics may therefore be in greater need of targeted support.

Fine and gross motor skills were significantly related to all 4 other outcomes included in the analysis: emergent numeracy; emergent literacy; mental flexibility; and emotion identification, though the effect sizes were relatively small (ranging from 0.15 to 0.44). There is a degree of consistency in that the models explain more variation for emerging literacy and emerging numeracy than they do for emotional identification and mental flexibility. The models for the emerging numeracy outcomes with fine and gross motor skills as predictors explained the most variation (49% and 46%), whilst the models for mental flexibility with fine and gross motor skills as predictors explained the least variation (25% and 26%). This means that there are other factors not measured in IELS that explain more of the variation in the outcomes of interest, particularly for gross motor skills. The literature suggests that executive function may have an important mediating role to play in these relationships, which is supported by the positive relationship identified between children’s physical development and mental flexibility in IELS.

Promoting awareness and understanding of motor skill development, its risk and protective factors, and the relationships between motor skills and other learning outcomes, may help teachers and practitioners intervene earlier and support children’s physical development in both the early years and KS1. Young children’s physical development warrants attention in its own right as a key area of development that also appears mutually supportive of other cognitive and non-cognitive areas of development.

This study suggests that physical development is more fundamental to children’s wellbeing and development than previously established. These findings are relevant for families, ECEC settings and primary schools, all of which have a key role in enhancing children’s physical development.

References

Ackerman, D.J. and Friedman-Krauss, A.H., 2017. Preschoolers' executive function: importance, contributors, research needs and assessment options. *ETS Research Report Series,* [e-journal] 10.1002/ets2.12148.

Albakri, M., Basi, T., Davies, M., Forsyth, E., Hopwood, V., Patel, R., Skipp, A. and Tanner, E., 2018. *Take-up of free early education entitlements.* [pdf]. Available at: <take-up of free early education entitlements> [Accessed 19 February 2021].

Allison, P., 2012. *When can you safely ignore multicollinearity?* [pdf] Available at: <when can you safely Ignore multicollinearity?>[Accessed 13 April 2021].

Asonitou, K., Koutsouki D. and Charitou, S., 2010. Motor skills and cognitive abilities as a precursor of academic performance in children with and without DCD. *Procedia Social and Behavioral Sciences,* [e-journal] 5(2010)**,** pp.1702–1707. 10.1016/j.sbspro.2010.07.350.

Asmussen, K., Law, J., Charlton, J., Acquah, D., Brims, L., Pote, I. and McBride, T., 2018. *Key competencies in early cognitive development: Things, people, numbers and words.* [pdf] Available at: <key competencies in early cognitive development: Things, people, numbers and words> [Accessed 19 February 2021].

Bhat, A., Landa R. and Galloway J., 2011. Current perspectives on motor functioning in infants, children, and adults with autism spectrum disorders. *Physical Therapy,* [e-journal] 91(7), pp.1116–1129. [pdf]. Available at: <current perspectives on motor functioning in infants, children, and adults with autism spectrum disorders> [Accessed 25 February 2021].

Bowyer-Crane, C., Bonetti, S., Compton, S., Nielsen, D., D'Apice, K. and Tracey, L., 2021. *The impact of Covid-19 on school starters: Interim briefing 1.* [pdf] Available at <the impact of Covid-19 on school starters: Interim briefing 1> [Accessed 24 April 2021].

Bürgi, F., Meyer, U., Granacher, U., Schindler, C., Marques-Vidal, P., Kriemler, S. and Puder, J. J., 2011. Relationship of physical activity with motor skills, aerobic fitness and body fat in preschool children: A cross-sectional and longitudinal study. (Ballabeina). *International Journal of Obesity,* [e-journal] 35(7), pp.937–944. 10.1038/ijo.2011.54

Burns, Y., O'Callaghan, M., McDonell, B. and Rogers, Y., 2004. Movement and motor development in ELBW infants at 1 year is related to cognitive and motor abilities at 4 years. *Early Human Development*, [e-journal] 80(1), pp.19–29. 10.1016/j.earlhumdev.2004.05.003.

Cai, L., 2010a. High-dimensional exploratory item factor analysis by a Metropolis-Hastings Robbins-Monro algorithm. *Psychometrika*, [e-journal] 75, 33–57. Available through: IDEAS website <IDEAS.respec.org> [Accessed 30 April 2021]. .

Cai, L., 2010b. Metropolis-Hastings Robbins-Monro algorithm for confirmatory item factor analysis. *Journal of Educational and Behavioral Statistics*, [e-journal] 35(3), 307–335. 10.3102/1076998609353115

Cai, L., 2017*. FlexMIRT Version 3.51: Flexible multilevel multidimensional item analysis and test scoring [computer software].* Chapel Hill, NC: Vector Psychometric Group.

Cameron, C.E, Brock, L.L., Murrah, W.M., Bell, L., Woralla, S.L., Grissmer, D. and Morrison F.J., 2012. Fine motor skills and executive function both contribute to kindergarten achievement. *Child Development*, [e-journal] 83(4), pp.1229–1244. 10.1111/j.1467-8624.2012.01768.x.

Carson, V., Hunter, S., Kizik, N., Wiebe, S.A., Spence, J.C., Friedman, A., Tremblay, M.S., Slater, L. and Hinkley, T., 2016. Systematic review of physical and cognitive development in early childhood. *Journal of Science and Medicine in Sport*, [e-journal] 19(7), pp.573 –578. 10.1016/j.jsams.2015.07.011

Charlton, C., Rasbash, J., Browne, W.J., Healy, M., and Cameron, B., 2019. MLwiN Version 3.04. Centre for Multilevel Modelling, University of Bristol.

Clements, D. H., Sarama, J. and Germeroth, C., 2016. Learning executive function and early mathematics: directions of causal relations. *Early Childhood Research Quarterly*, [e-journal] 36, pp.79–90. 10.1016/j.ecresq.2015.12.009.

Classick, R., Hope, C. and Sharp, C. (2021, forthcoming). IELS Thematic Report: Young Children's Development and Deprivation in England. Department of Education.

Cliff, D. P., Okely, A. D., Smith, L. M., and McKeen, K., 2009. Relationships between fundamental movement skills and objectively measured physical activity in preschool children. *Pediatric Exercise Science*, [e-journal] 21(4), pp.436–449. 10.1123/pes.21.4.436

Cronbach, L. J., 1951. Coefficient alpha and the internal structure of tests. *Psychometrika*, [e-journal] 16(3), pp. 297–334. [pdf]. Available at: <coefficient alpha and the internal structure of tests> [Accessed 30 April 2021].

Davids, E. and Roman, N., 2014. A systematic review of the relationship between parenting styles and children's physical activity. *African Journal for Physical Health Education, Recreation and Dance*, [e-journal] 20, pp.228 – 246 [online]. Available at:

<a_systematic_review_of_the_relationship_between_parenting_styles_and_children's_physical_activity >[Accessed 19 February 2021].

Davis, C. L., Tomporowski, P. D., McDowell, J. E., Austin, B. P., Miller, P. H., Yanasak, N. E., Allison, J. D. and Naglieri, J. A., 2011. Exercise improves executive function and achievement and alters brain activation in overweight children: A randomized, controlled trial. *Health Psychology*, [e-journal] 30(1), pp.91–98. 10.1037/a0021766.

Department for Education, 2018a. *Early years foundation stage profile: 2020 handbook.* [pdf] Available at: <early years foundation stage profile (EYFSP) results by pupil characteristics 2018> [Accessed 19 February 2021].

Department for Education 2018b. *Early years foundation stage profile (EYFSP) results by pupil characteristics 2018.* [pdf] Available at :<early years foundation stage profile (EYFSP) results by pupil characteristics 2018> [Accessed 19 February 2021].

Department for Education, 2020. *Early years foundation stage profile: 2021 handbook.* [pdf] Available at: <to early years foundation stage profile: 2021 handbook> [Accessed 19 February 2021].

Dinehart, L. and Manfra, L., 2013. Associations between low-income children's fine motor skills in preschool and academic performance in second grade. *Early Education and Development*, [e-journal] 24(2), pp.138–161.10.1080/10409289.2011.636729.

Diamond, A., 2012. Activities and programs that improve children's executive functions. *Current Directions in Psychological Science*, [e-journal] https://doi.org/10.1177/0963721412453722.

Donders, A., Rogier, T., van der Heijden, G. T., Stijnen, T. and Moons, K. G., 2006. A gentle introduction to imputation of missing values. *Journal of Clinical Epidemiology,* [e-journal] 59(10), pp.1087–1091. 10.1016/j.jclinepi.2006.01.014

Dyspraxia Foundation, 2016. *Dyspraxia/DCD in early years.* [pdf] Available at: <dyspraxiafoundation.org.uk/wp-content/uploads/2016/12/Early-year-s-dyspraxia-factsheet.pdf> [Accessed 19 February 2021].

Eddy, L.H., Wood, M.L., Shire, K.A., Bingham, D.D., Bonnick, E., Creaser, A., Mon-Williams, M. and Hill, L.J.B., 2018. A systematic review of randomized and case-controlled trials investigating the effectiveness of school-based motor skill interventions in 3- to 12-year-old children. *Child Care Health Dev,* [e-journal] 45(6), pp.773–790. 10.1111/cch.12712.

Education Endowment Foundation, 2019. *Physical development approaches* [online] Available at: <physical development approaches> [Accessed 19 February 2021].

Education Endowment Foundation, 2021. *Self-regulation strategies* [online] Available at <self-regulation approaches> [Accessed 1 March 2021].

Evans, J. and Roberts G., 1987. Physical competence and the development of children's peer relations. *Quest*, [e-journal] 39(1), pp. 23–35. 10.1080/00336297.1987.10483854.

Gorard, S. and See, B., eds., 2013. *Overcoming disadvantage in education.* Oxford: Routledge. 10.4324/9780203741665

Green, D., Charman, T., Pickles, A., Chandler, S., Loucas, T., Simonoff, E. and Baird, G., 2009. Impairment in movement skills of children with autistic spectrum disorders. *Developmental Medicine and Child Neurology*, [e-journal] 51(4), pp.311–316. [pdf]. Available at: impairment in movement skills of children with autistic spectrum disorders. [Accessed 30 April 2021].

Grissmer, D., Grimm, K.J., Aiyer, S.M., Murrah, W.M. and Steele, J.S., 2010. Fine motor skills and early comprehension of the world: Two new school readiness indicators. *Developmental Psychology,* [e-journal] 46(5), pp.1008–1017. 10.1037/a0020104

Hair, J. F. Jr., Anderson, R. E., Tatham, R. L. and Black, W. C., 1995. *Multivariate data analysis*. 3rd ed. New York, NY: Macmillan.

Hambleton, R.K., Swaminathan, H. and Rogers, H.J., 1991. Fundamentals of item response theory. *Applied Psychological Measurement*, [e-journal] 17(3), pp.293–294. 10.1177/014662169301700309.

Hartman, E., Houwen, S., Scherder, E. and Visscher, C., 2010. On the relationship between motor performance and executive functioning in children with intellectual disabilities. *Journal of Intellectual Disability Research,* [e-journal] 54(5), pp.468–477. 10.1111/j.1365-2788.2010.01284.x

Harvey, H and Miller, G., 2016. Executive function skills, early mathematics, and vocabulary in head start preschool children. *Early Education and Development*, [e-journal] 28(3), pp.290–307. 10.1080/10409289.2016.1218728

Houtenville, A. J. and Conway, K., 2008. Parental effort, school resources, and student achievement. *The Journal of Human Resources*, [e-journal] 43(2), pp. 437–453. [pdf] Available at: <parental effort, school resources, and student achievement> [Accessed 30 April 2021].

Hu, L. and Bentler, P.M., 2009. Cutoff criteria for fix indexes in covariance structure analysis: conventional criteria versus new alternatives. *Structural Equation Modeling: A Multidisciplinary Journal*, [e-journal] 6(1), pp.1–55. 10.1080/10705519909540118

Jacques, S. and Zelazo, P., 2005. On the possible roots of cognitive flexibility. In Homer, B. D. and Tamis-LeMonda, C. S., eds. *The development of social cognition and communication.* Mahwah, NJ: Lawrence Erlbaum Associates. pp.53–81.

Kaplan, B., Wilson, B. N., Dewey, D. and Crawford, S. G., 1998. DCD may not be a discrete disorder. *Human Movement Science*, [e-journal] 17(4-5), pp. 471–490 10.1016/S0167-9457(98)00010-4.

Kettlewell, K., Sharp, C. and Eivers, E., 2020a. *International early learning and child well-being study (IELS): National summary report for England*. [pdf] Available at: <international early learning and child well-being wtudy (IELS): national summary report for England> [Accessed 3 March 2021].

Kettlewell, K., Sharp, C., Lucas, M., Gambhir, G., Classick, R., Hope, C., Kollias, C. and Rutt, S., 2020b. *International early learning and child well-being study (IELS): National report for England*. [pdf] Available at: <international early learning and child well-being study (IELS): national report for England> [Accessed 3 March].

Kokštejn, J., Musálek, M. and Tufano, J. J., 2017. Are sex differences in fundamental motor skills uniform throughout the entire preschool period?. *PLoS ONE*, [e-journal] 12(4): e0176556. 10.1371/journal.pone.0176556.

LeFevre, J-A., Fast, L., Skwarchuk, S-L., Smith-Chant, B.L., Bisanz, J., Kamawar, D. and Penner-Wilger, M., 2010. Pathways to mathematics: longitudinal predictors of performance. *Child Development*, [e-journal] 81(6), pp.1753-1767. 10.1111/j.1467-8624.2010.01508.x.

Leonard, J., Garcia, A. and Schulz, L., 2019. Practice what you preach: how adults' actions, outcomes, and testimony affect preschoolers' persistence. *Child Development,* [e-journal] 2019, pp.1–18. [pdf] Available at: practice what you preach: how adults' actions, outcomes, and testimony affect preschoolers' persistence [Accessed 30 April 2021].

Livonen, S. and Sääkslahti, A.K., 2013. Preschool children's fundamental motor skills: a review of significant determinants. *Early Child Development and Care*, [e-journal] pp.1107-1126. 10.1080/03004430.2013.837897.

Lorah, J., 2020. Estimating a multilevel model with complex survey data: demonstration using TIMSS. *Journal of Modern Applied Statistical Methods*, [e-journal] 18(2), pp.2–20. [pdf] Available at: Estimating a multilevel model with complex survey data: demonstration using TIMSS. [Accessed 30 April 2021].

Macdonald, K., Milne, N., Orr, R. and Pope, R., 2020. Associations between motor proficiency and academic performance in mathematics and reading in year 1 school children: a cross-sectional study. *BMC Pediatrics,* [e-journal] 20(69). 10.1186/s12887-020-1967-8.

Macintyre, C., 2009. *Dyspraxia in the early years: Identifying and supporting children with movement difficulties* (2nd ed.). [online] Available at: 10.4324/9780203458006 [Accessed 22 February 2021].

Mathieson, K. and Banerjee, R., 2010. Pre-school peer play: The beginnings of social competence. *Educational & Child Psychology*, [e-journal] 27(1). <Pre-school peer play: the beginnings of social competence>.

McPhillips, M. and Jordan-Black, J.A., 2007. The effect of social disadvantage on motor development in young children: a comparative study. *Journal of Child Psychology and Psychiatry*, [e-journal] 48(12), pp.1214-1222. 10.1111/j.1469-7610.2007.01814.x.

Michel, E., Molitor, S. and Schneider, W., 2020. Executive functions and fine motor skills in kindergarten as predictors of arithmetic skills in elementary school. *Developmental Neuropsychology*, [e-journal] 45(6), pp.367-379. 10.1080/87565641.2020.1821033.

Miyake, A., Friedman, N., Emerson, M., Witzki, A., Howerter, A. and Wager T. The unity and diversity of executive functions and their contributions to complex "Frontal Lobe" tasks: a latent variable analysis. *Cogn Psychol*, [e-journal] 41(1), pp.49-100. 10.1006/cogp.1999.0734.

Muraki, E., 1992. A generalized partial credit model: Application of an EM algorithm. *ETS Research Report Series,* [e-journal] 1992(1), pp.i–30. 10.1002/j.2333-8504.1992.tb01436.x

National Health Service, 2021. *Developmental co-ordination disorder (Dyspraxia) in children*. [online] Available at: <developmental co-ordination disorder (Dyspraxia) In Children> [Accessed 22 February 2021].

Nezlek, J. B., 2008. An introduction to multilevel modeling for social and personality psychology. *Social and Personality Psychology Compass,* [e-journal] 2(2), pp. 842–860. 10.1111/j.1751-9004.2007.00059.x

Office for Standards in Education, Children's Services and Skills, 2020a. *COVID-19 series: briefing on early years, November 2020*. [pdf] Available at: <COVID-19 series: briefing on early years> [Accessed 22 February 2021].

Office for Standards in Education, Children's Services and Skills, 2020b. *COVID-19 series: briefing on schools, November 2020*. [pdf] Available at: <COVID-19 series: briefing on schools> [Accessed 22 February 2021].

Organisation for Economic Co-operation and Development, 2020. *Early Learning and Child Well-being in England.* [online] Available at: DOI 10.1787/c235abf9-en.

Organisation for Economic Co-operation and Development (2020a). Early learning and child well-being: a study of five-year-olds in England, Estonia, and the United States. [online] https://www.oecd-ilibrary.org/education/early-learning-and-child-well-being_3990407f-en

Organisation for Economic Co-operation and Development (2020b). *Early Learning and Child Well-being in England*. 10.1787/198d8c99-en

Organisation for Economic Co-operation and Development (2020c). Early Learning and Child Well-being in Estonia [online]. 10.1787/15009dbe-en

Organisation for Economic Co-operation and Development (2020d). Early Learning and Child Well-being in the United States [online]. 10.1787/198d8c99-en

Organisation for Economic Cooperation and Development, 2021. *International early learning and child well-being study: Technical report.* [pdf] Available at:<international early learning and child well-being study> [Accessed 3 March 2021].

Piek, J., Pitcher, T. and Hay, D., 1999. Motor coordination and kinaesthesis in boys with attention deficit-hyperactivity disorder. *Developmental Medicine and Child Neurology,* [e-journal] 41(3), pp. 159-165. 10.1111/j.1469-8749.1999.tb00575.x

Piek, J., Dyck, M., Nieman, A., Anderson, M., Hay, D., Smith, L., McCoy, M. and Hallmayer, J., 2004. The relationship between motor coordination, executive functioning and attention in school aged children. *Archives of Clinical Neurophyschology*, [e-journal] 19(8), pp.1063-1076. 10.1016/j.acn.2003.12.007

Pitchford, N.J., Papini, C., Outhwaite, L.A. and Gulliford, A., 2016. Fine motor skills predict maths ability better than they predict reading ability in the early primary school years. *Frontiers in Psychology*, [e-journal] 7(783). 10.3389/fpsyg.2016.00783.

Quigley, M.A., Poulsen, G., Boyle, E., Wolke, D., Field, D., Alfirevic, Z. and Kurinczuk, J.J., 2012. Early term and late preterm birth are associated with poorer school performance at age 5 years: a cohort study. *Archives of Disease in Childhood - Fetal and Neonatal Edition*, [e-journal] 97(3), pp.167–173. 10.1136/archdischild-2011-300888

Rosenbaum, D.A., Carlson, R.A. and Gilmore, R.O., 2001. Acquisition of intellectual and perceptual-motor skills. *Annual Review of Psychology*, [e-journal] 52, pp.453–70. 10.1146/annurev.psych.52.1.453.

Rubin, D. B., 1987. *Multiple imputation for nonresponse in surveys*. New York, NY: John Wiley & Sons, Inc.

Schmidt, M., Egger, F. Benzing, B., Jager, K., Conzeimann, A., Roebers, C.M. and Pesce, C., 2017. Disentangling the relationship between children's motor ability, executive function and academic achievement. *PLoS ONE*, [e-journal] 12(8). 10.1371/journal.pone.0182845.

Schmitt, S. A., Geldhof, G. J., Purpura, D. J., Duncan, R. and McClelland, M. M., 2017. Examining the relations between executive function, math, and literacy during the transition to kindergarten: A multi-analytic approach. *Journal of Educational Psychology*, [e-journal] 109(8), pp.1120–1140. 10.1037/edu0000193.

Serpel, Z.N. and Esposito A. G., 2016. Development of executive functions: implications for educational policy and practice. *Policy Insights from the Behavioral and Brain Sciences*, [e-journal] 3(2), pp.203-210. 10.1177/2372732216654718.

Sim, M., Bélanger, J., Hocking, L., Dimova, S., Lakovidou, E., Janta, B. and Teager, W., 2018. *Teaching, pedagogy and practice in early years childcare: an evidence review* [pdf]. Available at: <teaching, pedagogy and practice in early years childcare: an evidence review> [Accessed 22 February 2021].

Shuey, E. and Kankaraš, M., 2018. *The power and promise of early learning, OECD education working papers, No. 186.* [online] Available: Report link to the power and promise of early learning [Accessed 22 February 2021].

Sterne, J. A., White, I. R., Carlin, J. B., Spratt, M., Royston, P., Kenward, M. G. and Carpenter, J. R., 2009. Multiple imputation for missing data in epidemiological and clinical research: potential and pitfalls. *British Medical Journal*, [e-journal] 338, pp.157–160. 10.1136/bmj.b2393

Suggate, S., Pufke, E. and Stoeger, H., 2019. Children's fine motor skills in kindergarten predict reading in grade 1. *Early Childhood Research Quarterly*, [e-journal] 47, pp. 248-258. 10.1016/j.ecresq.2018.12.015.

Tabachnick, B. G. and Fidell, L. S., 2013. *Using multivariate statistics.* 6th ed. Boston, MA: Pearson.

Taber, K. S., 2018. The use of Cronbach's alpha when developing and reporting research instruments in science education. *Research in Science Education*, [e-journal] 48(6), pp.1273–1296. 10.1007/s11165-016-9602-2

Timmons, B.W., Naylor, P.J. and Pfeiffer, K.A., 2007. Physical activity for preschool children – how much and how?. *Applied Physiology*, *Nutrition, and Metabolism*, [e-journal] 32, Suppl 2, S122-134. https://doi.org/10.1139/H07-112

United Nations International Children's Emergency Fund 2018. *Learning through play*. [pdf] Available at: <learning through play> Accessed [22 February 2021].

Ursachi, G., Horodnic, I. A. and Zait, A., 2015. How reliable are measurement scales? External factors with indirect influence on reliability estimators. *Procedia Economics and Finance*, [e-journal] 20, pp. 679–686. 10.1016/S2212-5671(15)00123-9

Valentini, N., Pierosan, L., Rudisill, M. and Hastie, P., 2016. Mastery and exercise play interventions: motor skill development and verbal recall of children with and without disabilities. *Physical Education and Sport Pedagogy,* [e-journal] 22(4), pp.349-363. 10.1080/17408989.2016.1241223.

Van Buuren, S. and Groothuis-Oudshoorn, K., 2011. Mice: multivariate imputation by chained equations in R. *Journal of Statistical Software*, [e-journal] 45(3), pp.1-67. 10.18637/jss.v045.i03

Van der Fels, I., Te Wierike, S., Hartman, E., Elferink-Gemser, M., Smith, J. and Visscher, C., 2015. The relationship between motor skills and cognitive skills in 4–16 year old typically developing children: A systematic review. *Journal of Science and Medicine in Sport*, [e-journal] 18(6), pp.697-703.10.1016/j.jsams.2014.09.007.

Vasilopoulos, F. and Ellefson, M. R., 2021. Investigation of the associations between physical activity, self-regulation and educational outcomes in childhood. *PLoS ONE*, [e-journal], 16(5): e0250984. 10.1371/journal.pone.0250984

Venetsanou, F. and Kambas, A., 2010. Environmental factors affecting preschoolers' motor development. *Early Childhood Education Journal,* [e-journal] 37**,** 319–327. 10.1007/s10643-009-0350-z.

Verdine, B. N., Irwin, C. M., Golinkoff, R. M. and Hirsh-Pasek, K., 2014. Contributions of executive function and spatial skills to preschool mathematics achievement. *Journal of Experimental Child Psychology*, [e-journal] 126, pp.37–51. 10.1016/j.jecp.2014.02.012.

Vitiello, V., Greenfield, D., Munis, P. and George, J., 2011. Cognitive flexibility, approaches to learning and academic school readiness in head start preschool children. *Early Education & Development*, [e-journal] 22(3), pp.388 – 410. 10.1080/10409289.2011.538366

Yan, Z., Hong, S., Lui, F. and Su, Y. 2019. A meta-analysis of the relationship between empathy and executive function. *Psych Journal*, [e-journal] 9(1), pp.34-43. 10.1002/pchj.311.

Yen, W. M., 1984. Effects of local item dependence on the fit and equating performance of the three-parameter logistic model. *Applied Psychological Measurement*, [e-journal] 8(2), 125–145. 10.1177/014662168400800201

Yen, W. M., 1993. Scaling performance assessments: strategies for managing local item dependence. *Journal of Educational Measurement,* [e-journal] 30(3), pp.187–213. 10.1111/j.1745-3984.1993.tb00423.x

YouGov 2020. *Kindred² – School Readiness*. [pdf] Available at: <Kindred² – School Readiness> Accessed [24 April 2021].

Zelazo, P.D., Muller, U., Frye, D. and Marcovitch, S., 2003. The development of executive function in early childhood. *Monographs of the Society for Research in Child Development*, [e-journal] 68(3), vii-137. 10.3389/fpsyg.2014.00388

Zeng, N., Ayyub, M.A., Haichun, S., Wen X., Xiang, P. and Gao, Z., 2017. Effects of physical activity on motor skills and cognitive development in early childhood: A systematic review. *BioMed Research International*, [e-journal] 2017, Article ID 2760716. 10.1155/2017/2760716.

Zwicker, J. G. and Richardson Harris, S., 2008. Quality of life of formerly preterm and very low birth weight infants from preschool age to adulthood: a systematic review. *Pediatrics,* [e-journal] 121(2), pp.366-376. /10.1542/peds.2007-0169.

IELS Technical Appendix

Appendix A: Methodology

Introduction

The analysis sought to investigate associations between predictor variables and outcomes of interest in a multivariate manner, where confounding factors, correlated with both the outcome and predictor variables, were controlled for. Due to the clustered nature of the data, where children were nested within schools, multi-level modelling was used to conduct the analysis. The general approach was to build explanatory models in a quasi-forward selection manner where predictor variables were added one at a time in order of the strength of their univariate relationship with the outcome variable as long as they increased the predictive power of the multivariate model. Missing data was imputed before running the analysis. The rationale for the analysis approach and methodology used is explained in detail below.

Addressing missing data

Missing data was a challenge in the IELS analysis, especially for the parent questionnaire, although other sources of data had relatively high response rates. There were both unit missing data, where there were entire cases missing (that is, all the data from a survey was missing for one child), and values missing for specific variables in returned cases. Missing data could potentially introduce bias to the analysis, if, for example, there were more missing data from children with certain characteristics (for example, those from lower socio-economic status backgrounds). If only the complete cases were analysed, this would bias the analysis towards the group of respondents who answered. In addition, it is not valid to compare two models with differing amounts of missing data when using MLwiN (Version 3.04, Charlton and others, 2019) as this distorts the likelihood ratio statistic used to evaluate model significance multi-level modelling, as implemented in the software MLwiN. Multi-level modelling had to be used in this study because of the nature of the data where children were clustered within schools. This means that for correct inferences to be made about school- and pupil-level effects being analysed simultaneously a technique such as multi-level modelling has to be used that accounts for this clustering (Nezlek, 2008). Mean imputation is sometimes used as a remedy to the problem of missing data, but this is not the best solution. This method biases the analysis so that the more missing data a variable has, the less statistical power the study has to detect an effect that is there in reality in the population (Donders and others, 2006). This issue necessitated the use of multiple imputation, a technique that uses available data to estimate the likely values of missing data. It is the gold standard for dealing with missing data that provides the most unbiased estimate of its real values. Depending on the available data there will be varying degrees of uncertainty on the values of missing data using multiple imputation. If the present values on a variable can be predicted well from the other variables then there will be less uncertainty around its missing values, however if the prediction is poor then there will be greater uncertainty. Each imputed value in multiple imputation is a different random draw from a distribution of likely values so the degree of divergence of the imputed values between values reflects the degree of certainty of the estimates. The procedure works in a similar way to multiple regression, whereby a series of predictor variable are used to predict the missing values of an outcome variable in the dataset.

The IELS study had unit non-response rates of 32.71% for the parent questionnaire, 8.50% for part A of the teacher questionnaire (which asked about the teacher) and 10.24% for part B of the teacher questionnaire (which asked about the children). There was no unit missing data for the child assessment data. All 2,577 cases in the IELS dataset had complete assessment data across the 4 learning outcomes. In terms of individual variables, the economic and social status variables from the parent questionnaire had the highest non-response rates, especially household income (HHIncome) 40.1% non-response rate and Parent 1 Socioeconomic Index (44.2%) (the non-response rate for Parent 2 Socioeconomic Index was 43.4%). Full details of missing values for variables used in this report are given in Table 6.

Table 6 Missingness rates for IELS survey variables

Variable	Variable label	Percentage missing
ELADQ0501	The following questions ask/Was the child easily distracted during the assessments	1.05
ELADQ0502	The following questions ask/Did the child stay on task during the assessments	1.16
INVOLVE	Parent involvement	22.27
ELPAQ090100	ISCED 01 attendance – Age 0	32.71
ELPAQ090101	ISCED 01 attendance – Age 1	32.71
ELPAQ090102	ISCED 01 attendance – Age 2	32.71
ELPAQ090200	ISCED 02 attendance – Age 0	32.71
ELPAQ090201	ISCED 02 attendance – Age 1	32.71
ELPAQ090202	ISCED 02 attendance – Age 2	32.71
ELPAQ090203	ISCED 02 attendance – Age 3	32.71
ELPAQ090204	ISCED 02 attendance – Age 4	32.71

ELPAQ090205	ISCED 02 attendance – Age 5	32.71
ELPAQ09SVC00	Supervision and care attendance – Age 0	32.71
ELPAQ09SVC01	Supervision and care attendance – Age 1	32.71
ELPAQ09SVC02	Supervision and care attendance – Age 2	32.71
ELPAQ09SVC03	Supervision and care attendance – Age 3	32.71
ELPAQ09SVC04	Supervision and care attendance – Age 4	32.71
ELPAQ09SVC05	Supervision and care attendance – Age 5	32.71
ELPAQ1101	In a typical week/Read to your child from a book or e-book	33.33
ELPAQ1201	About how many children's books	33.45
ELPAQ0401	How often does your child/use computer, tablet	33.49
ICTDEV	Exposure to ICT devices	33.49
ELPAQ1108	In a typical week/Do things outside together like walking, ball games, swimming or cycling	33.53
ELPAQ1901	How old are Parents/Guardians – Parent/Guardian 1	33.57
IMMIG	Immigration background (dichotomous)	33.57
ELPAQ1111	In a typical week/Do educational activities	33.60
ELPAQ1113	In a typical week/Take your child to a special or paid activity outside of the home (for example, sports clubs, dance, swimming lessons, language lessons)	33.64
ELPAQ1103	In a typical week/Draw pictures	33.72
ELPAQ1109	In a typical week/Do activities – letters	34.19
Stud_Lang	Student language most often spoken at home	34.50
PAREDYRS	Highest number of years of formal education for either parent	34.96
ELPAQ2001	What is the highest level of formal education – Parent/Guardian 1	35.35
SES	SES index score	36.52
ELPAQ1902	How old are Parents/Guardians – Parent/Guardian 2	37.95
ELPAQ0601	Has your child ever experienced low birth weight?	38.40
ELPAQ2101	What is your annual household income	40.12
HHIncome	Household income (amount in national currency)	40.12
ELPAQ2002	What is the highest level of formal education – Parent/Guardian 2	42.03

P2SEI	Socio-economic index of occupation score for Parent 2	43.42
P1SEI	Socio-economic index of occupation score for Parent 1	44.16

In the current study, the MICE R statistical package (van Buuren and Groothuis-Oudshoorn, 2011, version 3.11.0) was used to impute missing data, in which Predictive Mean Matching was used for imputing missing numeric variable values and Multinomial Logistic Regression for missing categorical variable values. Predictive Mean Matching 'copies' actual values of a variable and replaces its missing values with them, see van Buuren and others (2011) for more details. This is done by identifying a set of transplant value candidates that occurred when the predictor variable values were similar to those where a missing value occurred, and randomly selecting one of these candidates for each imputation, and repeating the process for each missing value. Multinomial logistic regression is a regression technique that aims to predict unordered categorical outcome data based on predictor variables that are associated with each outcome. Each outcome is associated with a certain likelihood base on the predictor values, and the multiple imputation method selects between the possible outcomes randomly, based on the weightings of the likelihoods. Using these methods, 5 different imputed datasets were created to establish standard errors for coefficient values of multi-level models.

Addressing non-response bias

Non-response bias is an issue for multiple imputation as it is based on information provided by the available data. Therefore, for the process to function appropriately data should be missing at random, so that there is no bias in 'missingness' after accounting for the predictor variables. For example, there should not be more boys missing than girls. To prevent this from happening, using as many predictor variables as possible is recommended (Sterne and others, 2009). Consequently, in the IELS study the full range of available variables was used.

Multi-level modelling – general approach

The general approach taken with the multi-level modelling in this study was to build explanatory models of outcome variables using a quasi-forward variable selection technique. This involved a two-stage process for each model. First a series of single-variable models was created, one for each variable in a selection, which were either under investigation themselves or were to be controlled for before a variable or interaction term of interest was added, to investigate whether it significantly improved the predictive power of the model. The variables that were identified at this stage as being significant predictors of the dependent variable (learning outcomes) were then selected as candidates to be added into one multivariate model. This was done by first arranging them in descending order of significance based on their *t* statistics[31] and then considering each variable for inclusion in the model one at a time in that order. To be included in the model, a variable had to increase the predictive ability of the model. First the model started with only the constant, the mean value of the outcome variable, and then the most significant predictor from the single-variable models was tested to see if it increased the predictive power of the model. If it did, then this predictor would be added to the model and the next most significant predictor from the single-variable models would be tested, and so on. Likelihood ratio tests were used as the criterion to determine if a term led to a significant improvement in a model's statistical power, a statistic that reflects the amount of variance in the outcome measure explained by the model. To calculate this statistic the '-2 log likelihood' value for the model with a term being tested was subtracted from that for to a model with all previously added terms (which can be called the 'base model'). The resulting value was looked up on a chi square distribution for significance with the degrees of freedom being the number of extra terms added in the "test model" in addition to those in the base model. This was typically just the number of levels for a categorical variable added to a model or just a value of one for a continuous variable added, but the degrees of freedom were greater for some models where a series of interaction terms were included. All multi-level models were run with survey weights applied. Balanced repeat replicate weighting was not applied due to multi-level modelling being regarded as sufficient to account for the probability proportional to size sampling design of the IELS survey (Lorah, 2020).

Multi-level Modelling – implementation

Physical Development

For the physical development measure, the general approach described above was implemented to generate predictive models of fine and gross motor development. To determine whether fine and gross motor development was predictive of the four outcomes of interest (emergent numeracy, emergent literacy, mental flexibility, and emotional identification) an explanatory model was built of these outcomes without fine or gross motor skills as predictor variables. Then fine or gross motor skills were added to see if it significantly improved the predictive performance of the model. This ensured that any associations between fine or gross motor skills and outcome variables were not due to the effects of confounding variables associated with both fine or gross motor skill and the outcome variables.

[31] A t statistic is a standardised measure of significance calculated by dividing a regression slope coefficient by its standard error.

Multi-level modelling standard error calculation

Measurement error was quantified for both dependent variable values and missing independent variable values. For the dependent variables this information is available as a series of plausible values drawn from a distribution of likely values, and for the missing independent variable values this information is available as five different imputations drawn from a distribution of the likely missing values. This is an established method of running analysis for international large scale assessments (ILSAs) and used by OECD to correctly estimate standard errors for their surveys (OECD, 2021) for more information. Using Rubin's rule (Rubin, 1987) this measurement error information can be combined with sampling error to produce an overall standard error for coefficient estimates. With this procedure, variation in point estimates from inferential models (for example, variation in coefficient values from regression models) is used to estimate measurement variance. In the current study, plausible values were created by the IEA and were part of the dataset given to NFER before the multiple imputation of missing independent variable values was done. Therefore 25 unique datasets were created to avoid any bias that might be introduced with applying Rubin's rule with any particular combination of dependent variable plausible values and independent variable imputation values. Each dataset was a unique combination of independent variable imputations (imp) and dependent variable plausible values (pv). The 25 unique datasets were divided into 5 unique 'draws'. For example, draw 1 consisted of the following five data sets: i) imputation set 1 (imp1) and plausible values set 1 (pv1), ii) imputation set 2 (imp2) and plausible value set 2 (pv2), iii) imputation set 3 (imp3) and plausible value set 3 (pv3), (iv) imputation set 4 (imp4) and plausible value set 4 (pv4), (v) imputation set 5 (imp5) and plausible value set 5(pv5). Table 7 illustrates the 5 draws consisting of 5 unique combinations of an imputation set and a plausible value set.

Table 7 Illustration of the method used to estimate standard errors

Draw 1	Draw 2	Draw 3	Draw 4	Draw 5
imp1 & pv1	imp1 & pv2	imp1 & pv3	imp1 & pv4	imp1 & pv5
imp2 & pv2	imp2 & pv3	imp2 & pv4	imp2 & pv5	imp2 & pv1
imp3 & pv3	imp3 & pv4	imp3 & pv5	imp3 & pv1	imp3 & pv2
imp4 & pv4	imp4 & pv5	imp4 & pv1	imp4 & pv2	imp4 & pv3
imp5 & pv5	imp5 & pv1	imp5 & pv2	imp5 & pv3	imp5 & pv4

Rubin's rule (formula x) was applied to each of the 5 draws identified above in table 7, to derive 5 different measurement variance estimates, and the mean of these was as the final measurement variance estimate for each statistical test. This was then added to the sampling variance provided by MLwiN and the square root of this value taken as the final standard error. Final coefficient values were determined as the mean coefficient values across each of the 25 datasets.

Figure 18 Formula 1 Measurement variance calculation (Rubin, 1987).

$$\left[\left(1+\frac{1}{P}\right) * \frac{\sum_{p=1}^{P}\left(\varepsilon_{0,p}-\bar{\varepsilon}_{0,P}\right)^2}{P-1} \right]$$

P is the number of imputations $\varepsilon_{0,p}$ is the point estimate for a particular dataset $\bar{\varepsilon}_{0,P}$ the mean of the point estimates across datasets.

Significance testing

In order to determine whether individual coefficients within models were significantly different from zero, t values were calculated by dividing the final coefficient values described above by their final standard errors and the corresponding p value for 4 degrees of freedom calculated. Four degrees of freedom were used as 5 different datasets were used for calculating variance estimates.

The significance of models was performed in such a way that base models were compared to test models based on the same dataset (for example, base model on imp 1 & pv 1 was compared to test model on imp 1 & pv 1) yielding 25 base model – test model pairs. Each pair had to have a significant log likelihood ratio in order for the tested term or set of terms to be deemed to significantly increase the predictive performance of the model.

Calculating differences in months

Table 8 provides information to assess the confidence intervals for all measures included in this thematic report, based on the relationship between age in months and each measure (rather than the relationships between age and learning outcomes within the multi-level models, which include the influence of other variables on the learning outcomes). For example, the monthly difference mean for the emergent literacy outcome was 7.29 with a standard error of .57 and a confidence interval of ± 1.12 (1.96 x 0.57). If you resampled an infinite number of times from the population, each time getting a slightly different estimate of the population mean, and drew the confidence interval above around it, 95% of samples would contain the actual population mean. The confidence interval therefore provides an indication of the degree of uncertainty around mean estimates. Thus, for the emergent literacy outcome, every difference of 7.29 in the measure is equivalent to 1 month. In other words, a mean difference of 16.29 is equivalent to 2.24 (16.29 / 7.29 = 2.24) months.

It should be noted that confidence intervals also exist for mean differences. For measures where the mean difference between the youngest group of children (4 years and 11 months) and the oldest group of children (6 years and 0 months) was not statistically significant, the monthly mean difference was not estimated or reported (-).

Table 8 Average monthly difference for each outcome

Outcome	Monthly difference mean	Monthly difference S.E.	Confidence Interval
Emergent literacy	7.29	0.57	± 1.12
Emergent numeracy	9.80	0.57	± 1.12
Mental flexibility	6.28	0.75	± 1.47
Emotion identification	6.55	0.64	± 1.25
Fine motor skills	5.21	0.77	± 1.51
Gross motor skills*	N/A	N/A	N/A

*Children's age in months is not statistically significantly related to gross motor skill development so it was not appropriate to calculate monthly statistics.

Source: OECD IELS England database matched to NPD

Overview of assumption checking

Before starting on the analysis, a statistical analysis plan was drawn up by the NFER team for review and agreement with independent experts in early childhood education research and early childhood education policy at the DfE. This set out 5 assumption checks to be performed on the data, as set out below.

1. **Linearity**

   Checking that the outcome variables followed a linear relationship with continuous predictor variables.

2. **Normality of Residuals**

   Making sure that the residuals, which are the differences between model predictions and the actual data, are approximately normally distributed.

3. **Homogeneity of Variance**

Checking that residuals are homogenously distributed across the whole range of continuous predictor variables so that they are not systematically larger or smaller at any particular point on the scale.

4. **Independence of observations**

   Our multi-level models controlled for school-level clustering. Observations were then assumed to be independent at the child level and not clustered together by postcode or some other factor. The plan was to test this assumption by analysing whether the residuals were grouped together by any geographical data that might become available at the analysis stage.

5. **Multicollinearity**

   Predictor variables should not be correlated with each other when running regression-type models as this can lead to an underestimation of regression coefficient size, leading to a type-1 errors where real effects are missed. Principle components analysis (PCA) and correlation analyses on the predictor variables were planned to determine if multicollinearity of predictor variables was a problem.

Implementation of assumption checks

Due to the nature of the data some of the assumption checks were not possible and others had to be adjusted. It was not possible to check the Independence of observations check as no geographical data was available during the analysis to perform it, however this is often the case with survey studies and is typically not seen as a problem. The multicollinearity check had to be adjusted because the predictor variables were mostly categorical in nature, making a PCA analysis infeasible. Also the large number of predictors would have made interpretation of the PCA difficult. The PCA was therefore replaced with an analysis of the Variance Inflation Function (VIF), which calculates the degree to which multicollinearity between predictors is an issue for interpretation of a regression-type analysis.

Results of assumption checks

1. **Linearity**

   Visual inspection of bivariate scatter plots between continuous predictors and outcome variables showed that all of the relationships were approximately linear.

2. **Normality of Residuals**

   QQ plots of level-1 (pupil level) and level-2 (school level) residuals showed that they were approximately normally distributed.

3. **Homogeneity of Variance**

Visual inspection of scatter plots between continuous predictors and the outcome variables shows that residuals were approximately normally distributed.

4. **Multicollinearity and assumption checking – VIF**

When running multivariate analysis looking at the associations between many independent variables and a dependent variable, the issue of multicollinearity is a possible problem for any analysis. Given the data we are using it is fair to accept that there will be some correlation between background characteristics, but it is important to ensure that the correlation is not too high. Whilst the correlation matrix has been investigated for the analyses, an alternative method is to use the Variance Information Function (VIF). Running regression analysis through SPSS allows the VIF to be identified and whilst there would appear to be no universal agreement on what values are acceptable, a value of above 10 would indicate undesirable levels of collinearity (Hair and others, 1995). OLS regression models[32] were run for each of the learning outcomes as dependent variables and all relevant variables identified through the model selection process entered as independent variables[33]. The following tables identify the resulting outputs.

Table 9 Emergent numeracy– VIF

Variable	Variable label	VIF
SCHFSM	Proportion of Children on Free School Meals (Quartile)	2.96
PUPILFSM	Pupil level FSM (binary)	1.24
IDACIScore_15_AUT19	Child level IDACI Score	1.96
IDACIQUART	School IDACI Quartile	2.75
ITAGE	Child Age	1.76
YRGROUP	Child Year Group	1.74
ELPAQ090101	ISCED 01 attendance - Age 1	1.20
ELPAQ090205	ISCED 02 attendance – Age 5	1.21
ELPAQ090204	ISCED 02 attendance – Age 4	1.19
PAREDYRS	Highest number of years of formal education for either parent	5.87

[32] Analysis was completed on one of the imputed datasets and repeated on a second dataset to ensure consistency of findings.
[33] Additional models were run when using fine and gross motor skills as predictors and the resulting VIF's were very similar to those reported here. The VIF's for the motor skills variables were between 1.2 and 1.6.

SES	SES index score	3.42
INVOLVE	Parent involvement	1.09
ELADQ0501	The following questions ask/Was the child easily distracted during the assessments	2.02
ELADQ0502	The following questions ask/Did the child stay on task during the assessments	2.04
ELPAQ2001	What is the highest level of formal education – Parent/Guardian 1	3.22
ELPAQ2002	What is the highest level of formal education – Parent/Guardian 2	2.31
ELPAQ1901	How old are Parents/Guardians – Parent/Guardian 1	1.65
ELPAQ1902	How old are Parents/Guardians – Parent/Guardian 2	1.51
SEN2	Secondary SEN type	1.14
ELPAQ0401	How often does your child/use computer, tablet	1.04
ELPAQ1201	About how many children's books	1.55
TEACHPERSIST	Teacher rating of Child Persistence	1.09
ELPAQ1601	Number of siblings the child has	1.12
EAL	English as a Second Language	1.21
Overall effectiveness	OFSTED rating of school effectiveness	1.09
ELPAQ1113	In a typical week/Take your child to a special or paid activity outside of the home (e.g. sports clubs, dance, swimming lessons, language lessons)	1.23
IELSI014083	In a typical week how often do you do activities involving words and sentences with your child?	1.27
ELPAQ1101	In a typical week/Read to your child from a book or ebook	1.44

Table 10 Emergent literacy– VIF

Variable	Variable label	VIF
SCHFSM	Proportion of Children on Free School Meals (Quartile)	2.99
PUPILFSM	Pupil level FSM (binary)	1.25
IDACIScore_15_AUT19	Child level IDACI Score	2.00
IDACIQUART	School IDACI Quartile	2.79
eth_ASIA	Asian Ethnicity	5.58
eth_BLAC	Black Ethnicity	3.57
eth_MIXD	Mixed Ethnicity	4.48
eth_WHIT	White Ethnicity	10.66
ITSEX	Child Sex	1.04
ITAGE	Child Age	1.78
YRGROUP	Child Year Group	1.74
ELPAQ09SVC05	Supervision and care attendance – Age 5	2.61
ELPAQ09SVC03	Supervision and care attendance – Age 3	5.12
ELPAQ09SVC02	Supervision and care attendance – Age 2	6.09
ELPAQ09SVC01	Supervision and care attendance – Age 1	4.82
ELPAQ09SVC00	Supervision and care attendance – Age 0	2.68
ELPAQ090101	ISCED 01 attendance – Age 1	2.24
ELPAQ090100	ISCED 01 attendance – Age 0	2.18
ELPAQ090205	ISCED 02 attendance – Age 5	1.32
ELPAQ090204	ISCED 02 attendance – Age 4	1.21
PAREDYRS	Highest number of years of formal education for either parent	5.90
SES	SES index score	3.48
IMMIG	Immigration background (dichotomous)	1.97
INVOLVE	Parent involvement	1.12
ELADQ0501	The following questions ask/Was the child easily distracted during the assessments	2.03
ELADQ0502	The following questions ask/Did the child stay on task during the assessments	2.04

ELPAQ2001	What is the highest level of formal education – Parent/Guardian 1	3.25
ELPAQ2002	What is the highest level of formal education – Parent/Guardian 2	2.34
ELPAQ1901	How old are Parents/Guardians – Parent/Guardian 1	1.20
SEN2	NPD secondary SEN type	1.15
ELPAQ0401	How often does your child/use computer, tablet	1.04
ELPAQ1201	About how many children's books	1.66
TEACHPERSIST	Teacher rating of Child Persistence	1.10
ELPAQ1601	Number of siblings the child has	1.14
EAL	English as a second language	2.16
Overall effectiveness	OFSTED rating of school	1.10
ELPAQ1113	In a typical week/Take your child to a special or paid activity outside of the home (e.g. sports clubs, dance, swimming lessons, language lessons)	1.24
IELSI014083	In a typical week how many times do you do activities with your child involving words or sentences?	1.32
ELPAQ1101	In a typical week/Read to your child from a book or ebook	1.45
ELPAQ1104	In a typical week how many times do you have a back and forth conversation with your child?	1.14

Table 11 Emotion identification– VIF

Variable	Variable label	VIF
SCHFSM	Proportion of Children on Free School Meals (Quartile)	2.95
PUPILFSM	Pupil level FSM (binary)	1.22
IDACIScore_15_AUT19	Child level IDACI Score	1.95
IDACIQUART	School IDACI Quartile	2.70
ITSEX	Child Sex	1.04
ITAGE	Child Age	1.72
YRGROUP	Child Year Group	1.74
ELPAQ09SVC03	Supervision and care attendance – Age 3	4.25
ELPAQ09SVC02	Supervision and care attendance – Age 2	4.21
ELPAQ090204	ISCED 02 attendance – Age 4	1.11
PAREDYRS	Highest number of years of formal education for either parent	5.84
SES	SES index score	3.40
INVOLVE	Parent involvement	1.10
ELADQ0501	The following questions ask/Was the child easily distracted during the assessments	2.02
ELADQ0502	The following questions ask/Did the child stay on task during the assessments	2.04
ELPAQ2001	What is the highest level of formal education – Parent/Guardian 1	3.18
ELPAQ2002	What is the highest level of formal education – Parent/Guardian 2	2.28
ELPAQ1901	How old are Parents/Guardians – Parent/Guardian 1	1.19
SEN2	Secondary SEN Type from NPD database	1.14
ELPAQ1201	About how many children's books	1.48
TEACHPERSIST	Teacher rating of child persistence	1.09
ELPAQ1601	How many siblings does the child have	1.12
ELPAQ1113	In a typical week/Take your child to a special or paid activity outside of the home (e.g. sports clubs, dance, swimming lessons, language lessons)	1.22

IELSI014083	In a typical week how often do you do tasks involving words or sentences with your child?	1.31
ELPAQ1101	In a typical week/Read to your child from a book or ebook	1.44
ELPAQ1104	In a typical week how many times do you have a back and forth conversation with your child?	1.13

Table 12 Mental flexibility– VIF

Variable	Variable label	VIF
PUPILFSM	Proportion of Children on Free School Meals (Quartile)	1.20
IDACIScore_15_AUT19	Child level IDACI Score	1.75
IDACIQUART	School IDACI Quartile	1.72
ITAGE	Child Age	1.74
YRGROUP	Child Year Group	1.72
ELPAQ090205	ISCED 02 attendance – Age 5	1.09
PAREDYRS	Highest number of years of formal education for either parent	5.77
SES	SES index score	3.27
INVOLVE	Parent involvement	1.08
ELADQ0501	The following questions ask/Was the child easily distracted during the assessments	2.01
ELADQ0502	The following questions ask/Did the child stay on task during the assessments	2.02
ELPAQ2001	What is the highest level of formal education – Parent/Guardian 1	3.13
ELPAQ2002	What is the highest level of formal education – Parent/Guardian 2	2.27
SEN2	NPD secondary SEN	1.13
ELPAQ1201	About how many children's books	1.43
TEACHPERSIST	Teacher rating of Child Persistence	1.09
ELPAQ1113	In a typical week/Take your child to a special or paid activity outside of the home (e.g. sports clubs, dance, swimming lessons, language lessons)	1.19

IELSI014083	In a typical week how many times do you do activities with your child involving words or sentences?	1.26
ELPAQ1101	In a typical week/Read to your child from a book or ebook	1.42

Table 13 Fine motor skills– VIF

Variable	Variable label	VIF
PUPILFSM	Pupil level FSM (binary)	1.22
IDACIScore_15_AUT19	Child level IDACI Score	1.30
ITSEX	Child Sex	1.08
ITAGE	Child Age	1.71
YRGROUP	Child Year Group	1.72
PAREDYRS	Highest number of years of formal education for either parent	5.91
SES	SES index score	3.41
INVOLVE	Parent involvement	1.09
ELADQ0501	The following questions ask/Was the child easily distracted during the assessments	2.03
ELADQ0502	The following questions ask/Did the child stay on task during the assessments	2.05
ELPAQ2001	What is the highest level of formal education – Parent/Guardian 1	3.20
ELPAQ2002	What is the highest level of formal education – Parent/Guardian 2	2.27
ELPAQ1901	How old are Parents/Guardians – Parent/Guardian 1	1.16
SEN2	NPD secondary SEN type	1.15
ELPAQ0401	How often does your child/use computer, tablet	1.04
ELPAQ1201	About how many children’s books	1.42
TEACHPERSIST	Teacher rating of child persistence	1.09
ELPAQ1103	In a typical week/Draw pictures	1.15
ELPAQ1113	In a typical week/Take your child to a special or paid activity outside of the home (e.g. sports clubs, dance, swimming lessons, language lessons)	1.19

IELSI014083	In a typical week how many times do you do activities with your child involving words or sentences?	1.31
ELPAQ1101	In a typical week/Read to your child from a book or ebook	1.46

Table 14 Gross motor skills – VIF

Variable	Variable label	VIF
PUPILFSM	Pupil level FSM (binary)	1.13
ITSEX	Child Age	1.04
ITAGE	Child Age	1.06
SES	SES index score	1.97
INVOLVE	Parent involvement	1.06
ELADQ0501	The following questions ask/Was the child easily distracted during the assessments	2.04
ELADQ0502	The following questions ask/Did the child stay on task during the assessments	2.06
ELPAQ2001	What is the highest level of formal education – Parent/Guardian 1	1.68
SEN2	NPD secondary SEN type	1.14
ELPAQ1201	About how many children's books	1.22
TEACHPERSIST	Teacher rating of Child Persistence	1.07
ELPAQ1113	In a typical week/Take your child to a special or paid activity outside of the home (e.g. sports clubs, dance, swimming lessons, language lessons)	1.16

Correlation analysis showed that none of the predictor variables has a Pearson's correlation above 0.9 as recommended by Tabachnick and Fidell (2013). Analysis of the VIF values for the predictor variables entered into the multivariate models showed that there was only one value that was greater than 10 and given that this is due to its dichotomous nature rather than indicating a problem with multicollinearity, it is not considered an issue for our analysis (Allison, 2012). Together these findings indicate that multicollinearity was not an issue in this study.

Appendix B: Developing measures of fine and gross physical development

In order to measure fine and gross motor physical development appropriately, the IELS national team in England constructed interval-level item response theory (IRT) scales from the ordinal level likert-scale questionnaire response items provided by teachers, outlined below in Table 15. The fine motor scale was developed with the items labelled as 'fine' and the gross motor scale with the items labelled 'gross' in the column 'Motor development subtype'. Responses to these questions were provided on a 5-point scale of 'never', 'rarely', 'sometimes', 'often' or 'always'.

Table 15 The original physical development scale with 10 items

Item number	Question (rated on a scale of never (1), rarely (2), sometimes (3), often (4), always (5))	Motor development subtype
1	Does well at games or activities that involve catching objects	Gross
2	Does well at games or activities that involve throwing or kicking objects to reach a target (Note that this item was removed from the final measure.)	Gross
3	Successfully negotiates space when playing running and chasing games	Gross
4	Successfully draws basic shapes	Fine
5	Is able to use scissors to cut around a shape.	Fine
6	Can put on a coat without help, including zips and buttons	Fine
7	Confidently uses large-scale equipment	Gross
8	Jumps off an object and lands in a controlled way	Gross
9	Uses a pencil to write correctly formed numbers	Fine
10	Moulds modelling material such as clay or dough into shapes	Fine

Source: IELS main study Parent Questionnaire

The IELS dataset included 2,302 individual children whose teachers had rated their physical development. If children had any missing responses on the items used for constructing a subscale (5 items for fine motor, 4 for gross motor) then they were removed from the dataset used to create that motor subtype scale and a measure was not calculated for them. Inclusion and exclusion of children occurred independently between motor subtypes, that is to say that a child who had missing fine motor data would be removed from the fine motor dataset, but if they had complete gross motor data they would be included in the gross motor dataset, and vice versa. After excluding children based on their missing item responses the fine motor dataset had 2,249 children and the gross motor dataset had 2,197 children. Items were coded ‘never’ as 0, ‘rarely’ as 1, ‘sometimes’ as 2, ‘often’ as 3 and ‘always’ as 4, ready for IRT analysis.

IRT Model Construction

NFER mirrored the approach undertaken by the IELS International Consortium which developed the international IELS measures. The NFER team constructed fine and gross motor physical development scales from a simple 1-parameter logistic generalised partial credit model (Muraki, 1992), which was found to fit the observed responses well, after selecting the appropriate items as determined from graphical and chi-square analysis. Under this model, the only parameter that was allowed to differ between items was difficulty and all items had a common slope value, but this was optimised for the observed data rather than being fixed at 1 (as it would be in a polytomous Rasch model).

In order to correctly estimate standard errors in the analysis it was necessary to draw 5 plausible values from individual posterior ability distributions for the calculation of measurement variability. This was done using the Metropolis-Hastings Robbins-Monro (MH-RM) estimation method (Cai, 2010a; Cai, 2010b) implemented in the IRT software flexMirt (version 3.5.1; Cai, 2017). To avoid using item or person parameter values before the model had time to fully converge, the first 50 draws were discarded from the MH sampler for assumption checking statistics and for final scale development the first 500 were discarded. The thinning parameter in the final model was set to 100, meaning that every 100th draw of the MH sampler was retained. Model assumption checking was done on a single draw of ability values to avoid repeating the analysis 5 times. All models were weighted using the person weights provided by the IELS International Consortium (CHILDWGT).

Model Assumption Checking

Model assumption checking was done to ensure that the observed responses fitted the IRT model appropriately, that the items acted together to create a coherent measure of physical development and that the assessment was not biased towards certain subgroups of the population. Four assumption checks were done on the data, as outlined below.

Item Fit: To ensure that observed data fitted the IRT measurement model, the expected item characteristic curves and the response category characteristic curves were plotted and matched against the observed data. This ensured that each of the items fitted the IRT model used and sufficiently measured the same common trait tapped into across items. Chi-square tests on the observed and expected proportion corrects were also carried out as a formal test of item fit.

Dimensionality: As the physical development IRT scale was intended to measure physical development in general, it was necessary to ensure that the observed data were sufficiently unidimensional. This was of particular concern as the scale was constructed from both gross and fine motor items. These two classes of items needed to measure a common general physical development trait sufficiently in order to work together in creating an appropriate scale.

Differential Item Functioning (DIF): DIF analysis was conducted on the items used to construct both physical development subscales and revealed that no item was biased towards either boys or girls. This finding was confirmed graphically and statistically through a chi square analysis.

Local Dependence: In order to ensure that the items were not too narrowly focused on any particular areas of physical development, a Q3 analysis (Yen, 1984; Yen, 1993) was performed on the residuals between observed responses and expected performance. This was used to highlight any systematic similarities in the observed responses between items after accounting for the physical development ability of children as assessed by the IRT model. Item 1 and 2, assessing the gross motor skills of catching and throwing/kicking, respectively, were found to be highly correlated with each other on this analysis. The solution to this issue is addressed below.

Reliability

Although the scale was developed using Item Response Theory, Cronbach's alpha was also calculated (Cronbach, 1951), a statistic from classical test theory as an indicator of the reliability of the scale. Alpha values above 0.85 or higher are typically seen as indicating that an assessment has high reliability (Taber, 2017). However values of 0.95 or higher may indicate that an assessment is too narrowly focused or has redundant items (Ursachi, 2015). Q3 analysis (Yen, 1984; Yen, 1994) can help clarify if high alpha values are reflective of redundant items or items overly focused on one area of a domain.

Once all these assumption checks had been applied, a decision was taken on whether to exclude certain items while still retaining a balanced scale that equally measured fine and gross motor development. A conditioned model was then run using demographic variables and 5 plausible values were drawn from child posterior ability distributions for the calculation of appropriate standard errors later in the inferential analysis. These plausible value draws were scaled to have an overall mean of 500 and an overall standard deviation of 100 in line with OECD standards.

Initially all 5 gross motor items were used to construct the gross motor scale and all 5 fine motor items used to construct the fine motor scale, and the 4 assumption checks described above were carried out on each scale, along with computation of Cronbach's alpha.

Based on the local dependence between items 1 and 2, item 2 was removed from the gross motor scale so that it was not overly focused on throwing and catching activities. Question 1 was chosen instead of question 2, as it had slightly higher classical discrimination. The IELS national team in England then ran the IRT model for the gross motor scale again. The 4 assumption checks were carried out on each motor subtype model and corresponding data with the following results.

- The observed data showed good fit graphically and statistically to the model.
- Two methods were used to consider unidimensionality. Hambleton and others (1991) recommend a minimum ratio of the first to the second Eigen value of 5, and this was found for both the gross and fine motor data. Hu and Bentler (2009) recommend a Tucker Lewis Index (TLI) of 0.95 or greater, with a root mean square error of approximation (RMSEA) of less than 0.05. These criteria were partially met. For the fine motor scale, the TLI was 0.975 and its RMSEA was 0.089, which suggests that the data is sub-optimally unidimensional. For the gross motor scale the TLI was 0.761 and the RMSEA was 0.329. Here both criteria suggested that the data were less than optimally unidimensional. However these statistics are sensitive to low numbers of items, therefore the factor analysis together with the item fit statistics suggest that the data is sufficiently unidimensional to proceed with IRT analysis.
- None of the items showed statistically significant DIF by sex at the $p < 0.05$ level. This is in contrast to the overall physical development scale (see Kettlewell and others, 2020b) where DIF was found on item 5. DIF was found on item 5 of the overall physical development scale because it was calculated by finding violations in the observed performance relative to what would be expected based on a person's overall IRT ability value. This allowed a child's actual performance to shift significantly away from their expected performance with girls being better than expected, and boys worse than expected, on fine motor items. The reverse pattern was true on gross motor items. On the subscale DIF analysis each child's fine or gross subscale score was used as the basis for their expected performance so there was no discrepancy between expected and observed performance based on gender. The fine and gross motor estimates accurately matched actual behaviour on the respective items used to construct the scales.
- Overall, the two models showed suitable item fit, conditional independence and DIF statistics. In terms of dimensionality, the Eigen value statistics suggested that the data for both motor subtypes were sufficiently unidimensional according to the criteria set by Hambleton and others (1991), even though the root mean square error of approximation was above the recommended level for the fine motor scale

and there were violations on both the Tucker Lewis Index and the root mean square error of approximation for the gross motor scale. Therefore the analysis proceeded with using these item selections for final scale creation. The items used to construct the final subscales are shown in Table 16.

Table 16 Items used to construct each motor subscale

Item number	Question (rated on a scale of never, rarely, sometimes, often, always)	Motor development subtype
1	Does well at games or activities that involve catching objects	Gross
3	Successfully negotiates space when playing running and chasing games	Gross
4	Successfully draws basic shapes	Fine
5	Is able to use scissors to cut around a shape	Fine
6	Can put on a coat without help, including zips and buttons	Fine
7	Confidently uses large-scale equipment	Gross
8	Jumps off an object and lands in a controlled way	Gross
9	Uses a pencil to write correctly formed numbers	Fine
10	Moulds modelling material such as clay or dough into shapes	Fine

Source: IELS main study Parent Questionnaire

Model Conditioning and Z-Score Rescaling

It is important to prevent child ability values from centering together away from their true values due to the nature of IRT ability estimation algorithms. To prevent this from happening, the OECD International Consortium used the first principle components, sorted in descending order by their explanatory power, which explained 95% of the variation in the data constructed from all variables available as conditioning variables in their IRT modelling. However, this method was not practical in this case as there was a high degree of missing data which meant that it was only possible to construct principle components for a small number of cases that had values for all variables. The IELS national team in England therefore, selected variables that had complete cases in order to condition each of the IRT models (fine and gross motor). The following variables were used as conditioning variables: ELLITPV1 (emergent literacy plausible value 1), ELNUMPV1 (emergent numeracy plausible value 1), ELEEIPV1 (emotion identification plausible value 1), ELECAPV1 (emotion attribution plausible value 1), ELINHPV1 (inhibition plausible value 1), ELWMEPV1 (working memory plausible value 1), ELMFXPV1 (mental flexibility plausible value 1), ELEDPPV1 (teacher prosocial plausible value 1), ELEDDPV1 (teacher non-disruptive behaviour plausible value 1), ELEDTPV1 (teacher – trust plausible value 1), ITAGE (age of child at date of assessment), ITSEN (SEN status listed on administration tracking form), ITSEX (Gender listed on administration tracking form).

The OECD International Consortium scaled each of their IRT measures to have a mean of 500 and a standard deviation of 100. To provide comparability with these measures, the fine and gross motor development measures were treated in the same way. The plausible values were scaled overall so that the mean of all 5 draws collectively was set to 500 and their standard deviation to 100, this meant that the relative differences between plausible values were preserved and imputation variance, established as variation between the means of plausible value draws, could be calculated.

Sample Checking

Analysis for the fine and gross elements of physical development scale have been undertaken on a slightly reduced dataset from the original 2,577 used for the main analyses. There were 2,197 cases for models that included the gross motor measure and 2,249 for the fine motor measure. These measures have been used as both dependent and independent variables. As the number of cases is slightly different from the overall dataset, additional analysis was conducted to identify whether these reduced datasets were different from the overall dataset.

When these variables were used as predictors of emergent literacy, emergent numeracy, emotional identification and mental flexibility the best check is to look at whether the there is any significant difference between the mean scores for children who have the fine and gross measures and those children that do not. To test these possible differences analysis was run through the IDB Analyser and the output from those tests is given below.

Table 17 Checks on models using the fine motor scale as a predictor

Dependent variable	Do not have scale	Have scale	Mean Diff	Mean Diff SE	Mean Diff_t	sig
Emergent literacy	513.19	515.78	2.60	7.81	0.33	Non sig
Emergent numeracy	530.88	528.38	-2.50	7.75	-0.32	Non sig
Emotional identification	505.27	495.28	-10.00	6.50	-1.54	Non sig
Mental flexibility	519.53	511.87	-7.66	9.53	-0.80	Non sig

Source: IELS assessment of 2,302 children, age 5, England

Table 18 Checks on models using the gross motor scale as a predictor

Dependent variable	Do not have scale	Have scale	Mean Diff	Mean Diff SE	Mean Diff_t	sig
Emergent literacy	519.09	514.79	-4.31	7.91	-0.54	Non sig
Emergent numeracy	537.69	527.09	-10.60	7.95	-1.33	Non sig
Emotional identification	509.23	494.30	-14.93	6.33	-2.36	Sig
Mental flexibility	528.18	510.11	-18.07	8.70	-2.08	Sig

Source: IELS assessment of 2,302 children, age 5, England

It can be seen from Table 17 that there is no significant difference between the outcome scores for those children with and without a fine motor score. Table 18 identifies that for children with and without the gross motor score there is no significant difference in their emergent literacy and emergent numeracy scores, whilst the scores for emotional identification and mental flexibility are significantly different.

Where the fine motor and gross motor scores were used as outcomes, a slightly different analysis was run to establish if the those children with missing scores, and so excluded from the analysis, were also more likely to be missing other information that was included in the analysis. Logistic regression models were run using the dichotomous measure of whether a child had the outcome score or not. Tables 19 and 20 identify whether any of the independent variables are associated with being more or less likely in having a fine or gross motor skills score. Any significant variables (sig < 0.05) indicate that the models may not have fully accounted for the association of these variables with the outcome of interest.

Table 19 Checks on models with the fine motor scale as a dependent variable

Variable	Variable label	B	S.E.	Wald	df	Sig.
ITAGE	Child age	0.50	0.27	3.37	1	0.07
SCFSM	Proportion of children on free school seals (quartiles)	0.09	0.09	0.95	1	0.33
PUPILFSM	Pupil level FSM (binary)	-0.02	0.17	0.01	1	0.93
IDACIScore_15_AUT19	Child level IDACI score	-1.17	0.60	3.82	1	0.05
IDACIQUART	School IDACI quartile	-0.17	0.09	4.07	1	**0.04**
ITSEX	Child sex	-0.03	0.12	0.07	1	0.79
YRGROUP	Child year group	-0.18	0.22	0.71	1	0.40
ELPAQ09SVC05	Supervision and care attendance – Age 5	-0.21	0.14	2.15	1	0.14
ELPAQ09SVC03	Supervision and care attendance – Age 3	0.16	0.18	0.82	1	0.37
ELPAQ09SVC02	Supervision and care attendance – Age 2	0.35	0.19	3.35	1	0.07
ELPAQ09SVC01	Supervision and care attendance – Age 1	-0.43	0.18	5.63	1	**0.02**
ELPAQ09SVC00	Supervision and care attendance – Age 0	0.19	0.14	1.77	1	0.18
ELPAQ090101	ISCED 01 attendance – Age 1	0.21	0.11	3.97	1	0.05
ELPAQ090100	ISCED 01 attendance – Age 0	-0.16	0.11	1.91	1	0.17
ELPAQ090205	ISCED 02 attendance – Age 5	-0.04	0.07	0.27	1	0.60
ELPAQ090204	ISCED 02 attendance – Age 4	-0.06	0.09	0.46	1	0.50
PAREDYRS	Highest number of years of formal education for either parent	0.01	0.05	0.02	1	0.89
SES	SES index score	-0.08	0.12	0.49	1	0.48
IMMIG	Immigration background (dichotomous)	0.36	0.20	3.34	1	0.07
INVOLVE	Parent involvement	-0.18	0.13	1.81	1	0.18

Variable	Variable label	B	S.E.	Wald	df	Sig.
ELADQ0501	The following questions ask/Was the child easily distracted during the assessments	-0.11	0.09	1.62	1	0.20
ELADQ0502	The following questions ask/Did the child stay on task during the assessments	-0.03	0.12	0.06	1	0.80
ELPAQ2001	What is the highest level of formal education – Parent/Guardian 1	0.04	0.08	0.23	1	0.64
ELPAQ2002	What is the highest level of formal education – Parent/Guardian 2	0.03	0.06	0.26	1	0.61
ELPAQ1901	How old are Parents/Guardians – Parent/Guardian 1	-0.02	0.05	0.12	1	0.73
SEN2	NPD secondary SEN type	0.28	0.20	1.87	1	0.17
ELPAQ0401	How often does your child/use digital device	-0.02	0.06	0.08	1	0.78
ELPAQ1201	About how many children's books	0.02	0.06	0.11	1	0.74
TEACHPERSIST	Teacher rating of child persistence	-0.08	0.07	1.33	1	0.25
ELPAQ1601	Number of siblings the child has	0.02	0.06	0.14	1	0.71
NOT EAL	English as a second language	0.56	0.22	6.76	1	**0.01**
Overall effectiveness	OFSTED rating of school	-0.06	0.09	0.41	1	0.52
ELPAQ1113	In a typical week/Take your child to a special or paid activity outside of the home (e.g. sports clubs, dance, swimming lessons, language lessons)	-0.07	0.09	0.59	1	0.44
IELSI014083	In a typical week how many times do you do activities with your child involving words or sentences?	-0.07	0.07	0.93	1	0.34
ELPAQ1101	In a typical week/Read to your child from a book or ebook	0.14	0.08	3.10	1	0.08
ELPAQ1104	In a typical week how many times do you have	-0.03	0.07	0.14	1	0.71

Variable	Variable label	B	S.E.	Wald	df	Sig.
	a back and forth conversation with your child?					
Constant	-	-5.13	1.84	7.78	1	0.01

Source: IELS assessment of 2,302 children, age 5, England

Table 20 Checks on models with the gross motor scale as a dependent variable

Variable	Variable label	B	S.E.	Wald	df	Sig.
ITAGE	Child Age	0.44	0.25	2.94	1	0.09
SCHFSM	Proportion of children on free school meals (quartiles)	0.21	0.09	5.61	1	**0.02**
PUPILFSM	Pupil level FSM (binary)	0.05	0.16	0.09	1	0.77
IDACIScore_15_AUT19	Child level IDACI score	-1.06	0.56	3.58	1	0.06
IDACIQUART	School IDACI quartile	-0.07	0.08	0.80	1	0.37
ITSEX	Child sex	-0.06	0.12	0.30	1	0.59
YRGROUP	Child year group	-0.05	0.21	0.05	1	0.82
ELPAQ09SVC05	Supervision and care attendance – Age 5	-0.14	0.14	1.02	1	0.31
ELPAQ09SVC03	Supervision and care attendance – Age 3	0.00	0.17	0.00	1	1.00
ELPAQ09SVC02	Supervision and care attendance – Age 2	0.32	0.18	3.29	1	0.07
ELPAQ09SVC01	Supervision and care attendance – Age 1	-0.45	0.17	6.79	1	**0.01**
ELPAQ09SVC00	Supervision and care attendance – Age 0	0.15	0.13	1.20	1	0.27
ELPAQ090101	ISCED 01 attendance – Age 1	0.14	0.10	2.00	1	0.16
ELPAQ090100	ISCED 01 attendance – Age 0	-0.07	0.11	0.46	1	0.50
ELPAQ090205	ISCED 02 attendance – Age 5	-0.01	0.07	0.04	1	0.84
ELPAQ090204	ISCED 02 attendance – Age 4	0.00	0.09	0.00	1	0.99
PAREDYRS	Highest number of years of formal education for either parent	-0.02	0.05	0.24	1	0.62

Variable	Variable label	B	S.E.	Wald	df	Sig.
SES	SES index score	-0.06	0.11	0.30	1	0.58
IMMIG	Immigration background (dichotomous)	0.42	0.18	5.43	1	**0.02**
INVOLVE	Parent involvement	-0.05	0.13	0.18	1	0.67
ELADQ0501	The following questions ask/Was the child easily distracted during the assessments	-0.13	0.08	2.30	1	0.13
ELADQ0502	The following questions ask/Did the child stay on task during the assessments	-0.06	0.12	0.27	1	0.60
ELPAQ2001	What is the highest level of formal education – Parent/Guardian 1	0.07	0.07	0.79	1	0.37
ELPAQ2002	What is the highest level of formal education – Parent/Guardian 2	0.03	0.06	0.25	1	0.62
ELPAQ1901	How old are Parents/Guardians – Parent/Guardian 1	0.03	0.05	0.42	1	0.52
SEN2	NPD secondary SEN type	0.29	0.19	2.21	1	0.14
ELPAQ0401	How often does your child/use digital device	0.00	0.06	0.00	1	0.96
ELPAQ1201	About how many children's books	0.02	0.05	0.20	1	0.66
TEACHPERSIST	Teacher rating of child persistence	-0.09	0.07	1.85	1	0.17
ELPAQ1601	Number of siblings the child has	-0.01	0.05	0.02	1	0.89
NOT EAL	English as a second language	0.40	0.20	4.10	1	**0.04**
Overall effectiveness	OFSTED rating of school	0.02	0.08	0.05	1	0.82
ELPAQ1113	In a typical week/Take your child to a special or paid activity outside of the home (e.g. sports clubs, dance,	0.04	0.08	0.23	1	0.63

Variable	Variable label	B	S.E.	Wald	df	Sig.
	swimming lessons, language lessons)					
IELSI014083	In a typical week how many times do you do activities with your child involving words or sentences?	-0.08	0.07	1.27	1	0.26
ELPAQ1101	In a typical week/Read to your child from a book or ebook	0.10	0.08	1.90	1	0.17
ELPAQ1104	In a typical week how many times do you have a back and forth conversation with your child?	0.05	0.07	0.51	1	0.47
Constant	-	-5.72	1.73	10.99	1	0.00

Source: IELS assessment of 2,302 children, age 5, England

For cases missing the fine motor scale the model identifies that higher levels of IDACI deprivation are less likely to be missing a fine motor scale score and children who do not have English as an additional language are more likely to be missing the fine motor scale. Cases reporting higher attendance in supervised care at the age of one are also less likely to be missing the fine motor scale.

For cases missing the gross motor scale, the model identifies that higher levels of free school meal eligibility at the school level is associated with being more likely to be missing the gross motor score. The same likelihood is seen for higher attendance in supervise care at the age of one. For those with immigration status and for cases that do not have English as an additional language they are more likely to be missing the gross motor score.

The implications of this investigation are that if this dataset was complete and all cases had fine and gross motor scores the models might identify a slightly different association between these independent variables and children’s learning outcomes.

Appendix C: Final regression models and effect sizes

The following tables identify the amount of child variation[34] explained by each of the final models used in the IELS analysis. The percentage of variance explained by each model is calculated as follows. The initial stage of analysis is to run a 'base case' model which only contains the intercept and no explanatory variables. This model gives the variance at 2 levels: for schools and for children. The final model also provides these variances. By looking at the change in variance between the base and final models it is possible to understand how much child level variance has been accounted for by the variables in that model. There is a degree of consistency in that the models explain more variation for emerging literacy and emerging numeracy than they do for emotional identification and mental flexibility. The model for the emerging numeracy outcomes with fine motor skills as a predictor explained the most variation at 49%, whilst the model for the gross motor outcomes explained the least amount of variation at 22%.

Table 21 Variation explained for each of the models

Model	Variance Explained
Gross motor skills (GM)	22%
Fine motor skills (FM)	39%
Models with GM as explanatory variable	-
Emotion identification	27%
Emerging literacy	44%
Emerging numeracy	46%
Mental flexibility	26%
Models with FM as explanatory variable	-
Emotion identification	28%
Emerging literacy	46%
Emerging numeracy	49%
Mental flexibility	25%

[34] The amount of variance explained is calculated by finding the difference between the level 1 variance for the base case model and the level 1 variance in the final model.

Tables 22 and 23 show all the variables that were included in the final fine motor and gross motor models.

Table 22 Factors related to fine motor skills

Parameter	Estimate	Standard error	Sig.	Min.	Max.	Effect Size Mean	Standardised Coefficient
Base case							
School variance	1151.24	212.93	*	560.05	1742.43	-	-
Child variance	8854.60	430.84	*	7658.40	10050.79	-	-
Final model							
School variance	1007.06	201.66	*	447.16	1566.95	-	-
Child variance	5460.68	255.60	*	4751.04	6170.33	-	-
Reduction in child variance	-	-	-	-	**38.91%**	-	-
Constant	111.35	44.40	-	-11.91	234.61	-	-
Not at all distracted	45.52	10.04	*	17.66	73.39	0.46	0.23
Not really distracted	37.56	9.64	*	10.80	64.32	0.38	0.17
Distracted to some degree	21.97	8.52		-1.69	45.62	0.22	0.09
Not at all on task	-60.21	16.83	*	-106.94	-13.49	-0.60	-0.07
Not really on task	-20.24	9.34	-	-46.17	5.70	-0.20	-0.05
On task to some degree	-5.64	5.08	-	-19.74	8.46	-0.06	-0.03
Strong/moderate parental involvement	24.52	4.00	*	13.41	35.64	0.25	0.11
Age	49.21	7.60	*	28.10	70.31	0.20	0.14
Boy	-40.71	3.59	*	-50.69	-30.73	-0.41	-0.20
Child not eligible for FSM	12.20	4.98	-	-1.63	26.02	0.12	0.05
No SEN	44.38	6.48	*	26.38	62.38	0.44	0.15

Parameter	Estimate	Standard error	Sig.	Min.	Max.	Effect Size Mean	Standardised Coefficient
SES index score	6.04	2.15	*	0.08	12.01	0.08	0.06
Always persistent	127.30	15.37	*	84.62	169.97	1.27	0.29
Often persistent	71.41	11.77	*	38.74	104.08	0.71	0.32
Rarely persistent	2.72	11.42	-	-28.98	34.42	0.03	0.01
Sometimes persistent	30.73	11.17	-	-0.29	61.75	0.31	0.15

Source: IELS assessment of 2,249 children, age 5, England

Table 23 Factors related to gross motor skills

Parameter	Estimate	Standard error	Sig.	Min.	Max.	Effect Size Mean	Standardised Coefficient
Base case							
School variance	1637.96	280.64	*	858.78	2417.14	-	-
Child variance	8353.69	381.89	*	7293.40	9413.97	-	-
Final model							
School variance	1255.36	212.91	*	664.24	1846.49	-	-
Child variance	6433.09	314.91	*	5558.79	7307.40	-	-
Reduction in child variance	-	-	-	-	**22.38%**	-	-
Constant	383.74	16.11	*	339.02	428.46	-	-
Not at all distracted	32.12	10.80	*	2.14	62.09	0.32	0.16
Not really distracted	23.86	9.94	-	-3.74	51.46	0.24	0.11
Distracted to some degree	12.64	9.72	-	-14.34	39.63	0.13	0.05
Not at all on task	-56.92	20.66	-	-114.27	0.43	-0.57	-0.07
Not really on task	-15.71	10.40	-	-44.58	13.17	-0.16	-0.04

Parameter	Estimate	Standard error	Sig.	Min.	Max.	Effect Size Mean	Standardised Coefficient
On task to some degree	-0.49	6.27	-	-17.89	16.90	0.00	0.00
Attends a paid for activity 1-2 days/week	12.16	4.90	-	-1.44	25.75	0.12	0.06
Attends a paid for activity 3-4 days in a week	16.35	6.27	-	-1.05	33.75	0.16	0.06
Attends a paid for activity 5-7 days in a week	20.33	11.91	-	-12.75	53.40	0.20	0.04
Strong/moderate parental involvement	17.47	4.77	*	4.23	30.71	0.17	0.08
No SEN	50.29	6.46	*	32.34	68.23	0.50	0.17
Always persistent	112.41	16.68	*	66.09	158.72	1.12	0.26
Often persistent	58.20	13.43	*	20.90	95.49	0.58	0.26
Rarely persistent	-11.05	12.95	-	-47.01	24.91	-0.11	-0.04
Sometimes persistent	20.16	13.01	-	-15.95	56.27	0.20	0.10

Source: IELS assessment of 2,197 children, age 5, England

Tables 24, 25, 26 and 27 show all the variables, including fine motor skills, which were included in the final models for emergent numeracy, emergent literacy, mental flexibility and emotion identification.

Table 24 Factors related to emergent numeracy, including fine motor skills

Parameter	Estimate	Standard error	Sig.	Min.	Max.	Effect Size Mean	Standardised Coefficient
Base Case							
School variance	1356.52	209.31	*	775.40	1937.64	-	-
Pupil variance	8687.67	340.83	*	7741.41	9633.94	-	-
Final model							
School variance	669.00	113.91	*	352.76	985.25	-	-
Pupil variance	4460.21	170.64	*	3986.43	4933.98	-	-
Reduction in pupil variance	-	-	-	-	**48.79%**	-	-
Constant	-31.07	41.26	-	-145.63	83.48	-	-
Not at all distracted	35.87	9.63	*	9.13	62.60	0.36	0.18
Not really distracted	24.80	9.03	-	-0.27	49.88	0.25	0.11
Distracted to some degree	15.81	8.02	-	-6.46	38.08	0.16	0.06
Not at all on task	-74.46	13.99	*	-113.30	-35.63	-0.74	-0.09
Not really on task	-41.10	8.41	*	-64.46	-17.75	-0.41	-0.10
On task to some degree	-15.82	4.54	*	-28.42	-3.22	-0.16	-0.07
Up to 10 books	-3.21	15.66	-	-46.70	40.28	-0.03	-0.01
11-25 books	6.88	17.33	-	-41.24	54.99	0.07	0.02
26-50 books	10.14	16.95	-	-36.92	57.19	0.10	0.04
51-100 books	20.61	17.10	-	-26.87	68.09	0.21	0.09
More than 100 books	25.23	16.64	-	-20.98	71.43	0.25	0.11
School IDACI 2nd least deprived	31.46	6.68	*	12.91	50.02	0.31	0.13
School IDACI 2nd most deprived	13.02	7.43	-	-7.61	33.64	0.13	0.05

Parameter	Estimate	Standard error	Sig.	Min.	Max.	Effect Size Mean	Standardised Coefficient
School IDACI least deprived	36.22	7.04	*	16.68	55.76	0.36	0.17
Strong/moderate parental involvement	10.51	4.16	-	-1.04	22.06	0.10	0.05
Age	50.44	7.33	*	30.10	70.79	0.21	0.15
Fine Motor Score	0.31	0.02	*	0.25	0.37	0.44	0.31
No SEN	26.02	6.15	*	8.95	43.10	0.26	0.09
SES index score	9.48	2.34	*	2.97	15.99	0.13	0.09
Always persistent	26.74	11.54	-	-5.30	58.78	0.27	0.06
Often persistent	19.07	9.58	-	-7.54	45.68	0.19	0.08
Rarely persistent	-11.42	10.32	-	-40.08	17.25	-0.11	-0.04
Sometimes persistent	8.30	8.84	-	-16.25	32.85	0.08	0.04
Year 1	40.40	5.59	*	24.87	55.93	0.40	0.15

Source: IELS assessment of 2,249 children, age 5, England

Table 25 Factors related to emergent literacy, including with fine motor

Parameter	Estimate	Standard error	Sig.	Min.	Max.	Effect Size Mean	Standardised Coefficient
Base case							
School variance	1638.86	276.90	*	870.06	2407.65	-	-
Pupil variance	7987.53	364.74	*	6974.86	9000.19	-	-
Final model							
School variance	585.64	154.90	*	155.57	1015.70	-	-
Pupil variance	4362.78	186.74	*	3844.31	4881.25	-	-
Reduction in pupil variance	-	-	-	-	**45.77%**	-	-

Parameter	Estimate	Standard error	Sig.	Min.	Max.	Effect Size Mean	Standardised Coefficient
Constant	33.24	40.82	-	-80.10	146.58	-	-
English is main language	30.64	5.49	*	15.39	45.89	0.31	0.12
Not at all distracted	40.49	8.57	*	16.69	64.29	0.41	0.20
Not really distracted	29.01	8.61	*	5.10	52.92	0.30	0.13
Distracted to some degree	19.57	8.00	-	-2.64	41.78	0.20	0.08
Not at all on task	-63.23	14.96	*	-104.76	-21.70	-0.64	-0.08
Not really on task	-35.77	9.32	*	-61.65	-9.89	-0.36	-0.09
On task to some degree	-13.96	5.35	-	-28.82	0.89	-0.14	-0.07
Uses digital device at least once a month	29.37	9.06	*	4.21	54.54	0.30	0.08
Uses digital device at least once a week	10.02	7.01	-	-9.44	29.49	0.10	0.05
Uses digital device everyday	16.40	7.25	-	-3.72	36.51	0.17	0.08
Attends paid for activity 1-2 days a week	10.90	4.30	-	-1.02	22.83	0.11	0.06
Attends paid for activity 3-4 days a week	8.68	7.09	-	-11.01	28.37	0.09	0.03
Attends paid for activity 5-7 days a week	1.50	10.89	-	-28.75	31.74	0.02	0.00
Up to 10 books	4.41	14.32	-	-35.36	44.18	0.05	0.01
11-25 books	13.52	16.15	-	-31.32	58.36	0.14	0.05

Parameter	Estimate	Standard error	Sig.	Min.	Max.	Effect Size Mean	Standardised Coefficient
26-50 books	4.14	14.26	-	-35.46	43.74	0.04	0.02
51-100 books	24.65	14.92	-	-16.79	66.08	0.25	0.11
More than 100 books	31.46	14.19	-	-7.93	70.86	0.32	0.14
School IDACI: 2nd least deprived quartile	26.60	6.34	*	9.01	44.19	0.27	0.12
School IDACI: 2nd most deprived quartile	8.80	7.90	-	-13.13	30.73	0.09	0.03
School IDACI: least deprived quartile	32.92	6.68	*	14.37	51.47	0.34	0.15
Strong/moderate parental involvement	10.56	3.92	-	-0.31	21.43	0.11	0.05
Age	35.20	7.08	*	15.53	54.87	0.15	0.11
Fine motor score	0.23	0.02	*	0.17	0.29	0.34	0.24
No SEN	35.96	6.08	*	19.09	52.83	0.37	0.12
SES index score	9.50	2.26	*	3.22	15.79	0.13	0.09
Always persistent	23.26	14.21	-	-16.18	62.71	0.24	0.05
Often persistent	15.02	12.94	-	-20.92	50.96	0.15	0.07
Rarely persistent	-16.75	13.74	-	-54.89	21.39	-0.17	-0.06
Sometimes persistent	0.90	12.47	-	-33.72	35.51	0.01	0.00
Year 1	31.24	5.84	*	15.03	47.45	0.32	0.12

Source: IELS assessment of 2,249 children, age 5, England

Table 26 Factors related to mental flexibility, including fine motor skills

Parameter	Estimate	Standard error	Sig.	Min.	Max.	Effect Size Mean	Standardised Coefficient
Base case							
School variance	657.19	186.62	*	139.06	1175.32	-	-
Pupil variance	10762.50	389.39	*	9681.41	11843.60	-	-
Final model							
School variance	745.39	183.85	*	234.95	1255.83	-	-
Pupil variance	8080.31	287.45	*	7282.22	8878.39	-	-
Reduction in pupil variance	-	-	-	-	**25.04%**	-	-
Constant	223.76	58.38	*	61.68	385.84	-	-
Not at all distracted	34.50	12.13	*	0.83	68.16	0.32	0.16
Not really distracted	12.86	10.98	-	-17.64	43.35	0.12	0.05
Distracted to some degree	12.27	11.21	-	-18.84	43.39	0.11	0.05
Not at all on task	-82.28	23.60	*	-147.80	-16.76	-0.77	-0.09
Not really on task	-68.78	10.89	*	-99.01	-38.55	-0.64	-0.16
On task to some degree	-24.57	6.92	*	-43.77	-5.37	-0.23	-0.11
Strong/moderate parental involvement	8.57	4.83	-	-4.84	21.99	0.08	0.04
Age	22.51	10.22	-	-5.87	50.89	0.09	0.06
Fine motor score	0.18	0.03	*	0.10	0.27	0.24	0.17
No SEN	21.53	7.89	-	-0.37	43.43	0.20	0.07
SES index score	6.62	2.64	-	-0.72	13.95	0.08	0.06
Always persistent	22.87	14.19	-	-16.52	62.26	0.21	0.05

Parameter	Estimate	Standard error	Sig.	Min.	Max.	Effect Size Mean	Standardised Coefficient
Often persistent	26.46	11.86	-	-6.48	59.39	0.25	0.11
Rarely persistent	-3.44	12.09	-	-37.01	30.12	-0.03	-0.01
Sometimes persistent	15.91	10.63	-	-13.59	45.41	0.15	0.07
Year 1	28.20	7.61	*	7.07	49.32	0.26	0.10

Source: IELS assessment of 2,249 children, age 5, England

Table 27 Factors related to emotion identification, including fine motor skills

Parameter	Estimate	Standard error	Sig.	Min.	Max.	Effect Size Mean	Standardised Coefficient
Base case							
School variance	687.69	181.73	*	183.12	1192.26	-	-
Pupil variance	8599.90	344.94	*	7642.19	9557.60	-	-
Final model							
School variance	661.16	147.63	*	251.29	1071.02	-	-
Pupil variance	6230.68	239.35	*	5566.14	6895.22	-	-
Reduction in pupil variance	-	-	-	-	**27.86%**	-	-
Constant	-25.67	50.20	-	-165.05	113.71	-	-
Not at all distracted	42.86	11.63	*	10.57	75.14	0.44	0.22
Not really distracted	31.61	10.23	*	3.20	60.01	0.33	0.15
Distracted to some degree	22.67	10.31	-	-5.96	51.30	0.24	0.10
Not at all on task	-54.82	19.94	-	-110.18	0.54	-0.57	-0.07
Not really on task	-28.33	10.61	-	-57.79	1.12	-0.29	-0.07
On task to some degree	-1.77	6.46	-	-19.71	16.17	-0.02	-0.01

Parameter	Estimate	Standard error	Sig.	Min.	Max.	Effect Size Mean	Standardised Coefficient
Have a back-and-forth conversation 1-2 days in a week	36.46	12.78	*	0.97	71.96	0.38	0.13
Have a back-and-forth conversation 3-4 days in a week	27.64	11.55	-	-4.42	59.69	0.29	0.13
Have a back-and-forth conversation 5-7 days in a week	36.97	11.44	*	5.20	68.75	0.38	0.19
Up to 10 books	11.97	22.30	-	-49.93	73.88	0.12	0.04
11-25 books	29.70	24.30	-	-37.77	97.17	0.31	0.10
26-50 books	14.15	23.25	-	-50.40	78.71	0.15	0.06
51-100 books	27.90	22.67	-	-35.03	90.83	0.29	0.13
More than 100 books	27.96	23.13	-	-36.25	92.16	0.29	0.13
Age	54.26	7.90	*	32.33	76.19	0.23	0.16
Boy	-15.94	4.77	*	-29.19	-2.70	-0.17	-0.08
Fine motor score	0.18	0.03	*	0.10	0.26	0.26	0.19
Pupil not eligible for FSM	10.80	5.39	-	-4.16	25.75	0.11	0.04
No SEN	34.01	7.34	*	13.64	54.39	0.35	0.12
Always persistent	29.32	14.71	-	-11.53	70.18	0.30	0.07
Often persistent	20.94	12.73	-	-14.41	56.30	0.22	0.10
Rarely persistent	6.51	12.17	-	-27.28	40.31	0.07	0.02
Sometimes persistent	16.54	11.63	-	-15.75	48.83	0.17	0.09

Source: IELS assessment of 2,249 children, age 5, England

Tables 28, 29, 30 and 31 include all the variables, including gross motor skills, which were included in the final models for emergent numeracy, emergent literacy, mental flexibility and emotion identification.

Table 28 Factors related to emergent numeracy, including gross motor skills

Parameter	Estimate	Standard error	Sig.	Min.	Max.	Effect Size Mean	Standardised Coefficient
Base case							
School variance	1406.84	218.87	*	799.18	2014.50	-	-
Pupil variance	8695.12	335.25	*	7764.34	9625.91	-	-
Final model							
School variance	730.26	124.71	*	384.02	1076.49	-	-
Pupil variance	4706.86	177.18	*	4214.95	5198.77	-	-
Reduction in pupil variance	-	-	-	-	**45.99%**	-	-
Constant	-52.72	42.65	-	-171.14	65.70	**-**	**-**
Not at all distracted	44.53	10.23	*	16.14	72.93	0.44	0.22
Not really distracted	31.53	9.40	*	5.44	57.63	0.31	0.14
Distracted to some degree	20.27	8.39	-	-3.04	43.58	0.20	0.08
Not at all on task	-83.99	15.21	*	-126.21	-41.76	-0.83	-0.10
Not really on task	-44.96	8.80	*	-69.40	-20.52	-0.45	-0.11
On task to some degree	-18.96	4.70	*	-32.02	-5.91	-0.19	-0.09
Up to 10 books	-1.97	18.62	-	-53.66	49.72	-0.02	-0.01
11-25 books	12.47	21.28	-	-46.60	71.54	0.12	0.04
26-50 books	13.19	20.48	-	-43.66	70.05	0.13	0.05
51-100 books	24.47	20.90	-	-33.55	82.48	0.24	0.11
More than 100 books	29.78	20.60	-	-27.42	86.97	0.30	0.13

Parameter	Estimate	Standard error	Sig.	Min.	Max.	Effect Size Mean	Standardised Coefficient
School IDACI: 2nd least deprived quartile	30.84	7.07	*	11.21	50.47	0.31	0.13
School IDACI: 2nd most deprived quartile	11.62	7.57	-	-9.39	32.62	0.12	0.04
School IDACI: least deprived quartile	35.63	7.60	*	14.52	56.74	0.35	0.16
Strong/moderate parental involvement	14.29	4.40	*	2.07	26.50	0.14	0.07
Age	59.33	7.31	*	39.03	79.63	0.25	0.17
Gross motor score	0.20	0.02	*	0.15	0.26	0.29	0.20
No SEN	29.72	6.38	*	12.02	47.42	0.30	0.10
SES index score	10.19	2.42	*	3.48	16.89	0.14	0.10
Always persistent	42.63	11.88	*	9.65	75.62	0.42	0.10
Often persistent	29.06	10.42	*	0.12	57.99	0.29	0.13
Rarely persistent	-10.00	10.99	-	-40.51	20.51	-0.10	-0.04
Sometimes persistent	11.63	9.49	-	-14.73	37.99	0.12	0.06
Year 1	46.70	5.67	*	30.96	62.44	0.46	0.17

Source: IELS assessment of 2,197 children, age 5, England

Table 29 Factors related to emergent literacy, including gross motor skills

Parameter	Estimate	Standard error	Sig.	Min.	Max.	Effect Size Mean	Standardised Coefficient
Base case							
School variance	1657.04	275.52	*	892.10	2421.99	-	-
Pupil variance	7974.63	369.33	*	6949.22	9000.04	-	-

Parameter	Estimate	Standard error	Sig.	Min.	Max.	Effect Size Mean	Standardised Coefficient
Final model							
School variance	634.03	158.51	*	193.93	1074.12	-	-
Pupil variance	4501.28	194.62	*	3960.94	5041.63	-	-
Reduction in pupil variance	-	-	-	-	**43.98%**	-	-
Constant	22.42	43.16	-	-97.40	142.25	-	-
English is main language	26.91	5.55	*	11.50	42.33	0.27	0.10
Not at all distracted	47.56	9.18	*	22.07	73.06	0.48	0.24
Not really distracted	34.60	8.86	*	10.01	59.19	0.35	0.16
Distracted to some degree	23.52	8.17	*	0.85	46.19	0.24	0.10
Not at all on task	-70.11	15.74	*	-113.80	-26.42	-0.71	-0.09
Not really on task	-38.86	9.58	*	-65.46	-12.25	-0.40	-0.10
On task to some degree	-15.66	5.41	*	-30.69	-0.64	-0.16	-0.07
Uses digital device at least once a month	30.99	9.49	*	4.65	57.33	0.32	0.09
Uses digital device at least once a week	11.70	7.27	-	-8.49	31.88	0.12	0.06
Uses digital device everyday	16.35	7.52	-	-4.54	37.24	0.17	0.08
Attends paid for activity 1-2 days a week	9.67	4.59	-	-3.09	22.43	0.10	0.05

Parameter	Estimate	Standard error	Sig.	Min.	Max.	Effect Size Mean	Standardised Coefficient
Attends paid for activity 3-4 days a week	8.10	7.39	-	-12.42	28.62	0.08	0.03
Attends paid for activity 5-7 days a week	-0.25	11.11	-	-31.11	30.60	0.00	0.00
Up to 10 books	4.64	16.50	-	-41.16	50.44	0.05	0.01
11-25 books	17.35	18.79	-	-34.83	69.53	0.18	0.06
26-50 books	7.22	16.57	-	-38.78	53.23	0.07	0.03
51-100 books	27.61	17.26	-	-20.32	75.54	0.28	0.13
More than 100 books	34.87	16.18	-	-10.04	79.78	0.36	0.16
School IDACI:2nd least deprived quartile	26.77	6.71	*	8.14	45.40	0.27	0.12
School IDACI:2nd most deprived quartile	7.56	7.90	-	-14.36	29.49	0.08	0.03
School IDACI: least deprived quartile	33.23	7.03	*	13.72	52.74	0.34	0.16
Strong/moderate parental involvement	13.01	4.05	*	1.77	24.26	0.13	0.06
Age	40.47	7.18	*	20.52	60.41	0.17	0.12
Gross motor score	0.16	0.02	*	0.11	0.22	0.24	0.17
No SEN	36.60	6.50	*	18.55	54.65	0.37	0.12
SES index score	9.97	2.38	*	3.37	16.58	0.14	0.10
Always persistent	35.80	14.10	-	-3.35	74.94	0.36	0.09
Often persistent	22.76	13.24	-	-14.00	59.51	0.23	0.10

Parameter	Estimate	Standard error	Sig.	Min.	Max.	Effect Size Mean	Standardised Coefficient
Rarely persistent	-15.36	14.14	-	-54.62	23.91	-0.16	-0.06
Sometimes persistent	4.31	12.63	-	-30.75	39.37	0.04	0.02
Year 1	36.39	5.96	*	19.85	52.93	0.37	0.14

Source: IELS assessment of 2,197 children, age 5, England

Table 30 Factors related to mental flexibility, including gross motor skills

Parameter	Estimate	Standard error	Sig.	Min.	Max.	Effect Size Mean	Standardised Coefficient
Base case							
School variance	633.46	180.22	*	133.10	1133.82	-	-
Pupil variance	10755.86	389.67	*	9673.98	11837.73		
Final model						-	-
School variance	777.73	188.95	*	253.13	1302.32	-	-
Pupil variance	8004.59	289.55	*	7200.69	8808.49	-	-
Reduction in pupil variance	-	-	-	-	**25.59%**	-	-
Constant	194.74	59.29	*	30.14	359.35	-	-
Not at all distracted	36.98	12.01	*	3.64	70.32	0.35	0.17
Not really distracted	13.43	11.17	-	-17.59	44.44	0.13	0.06
Distracted to some degree	13.34	11.84	-	-19.52	46.21	0.12	0.05
Not at all on task	-86.30	23.84	*	-152.49	-20.11	-0.81	-0.10
Not really on task	-70.90	11.09	*	-101.69	-40.11	-0.66	-0.16
On task to some degree	-25.80	6.95	*	-45.10	-6.49	-0.24	-0.11

Parameter	Estimate	Standard error	Sig.	Min.	Max.	Effect Size Mean	Standardised Coefficient
Doing words and sentences activities 1-2 days in a week	10.35	11.26	-	-20.91	41.61	0.10	0.04
Doing words and sentences activities 3-4 days in a week	20.42	10.19	-	-7.88	48.72	0.19	0.09
Doing words and sentences activities 5-7 days in a week	25.46	10.79	-	-4.49	55.41	0.24	0.11
Age	26.85	10.41	-	-2.04	55.74	0.10	0.07
Gross motor score	0.16	0.03	*	0.09	0.23	0.21	0.15
No SEN	23.61	7.63	*	2.43	44.78	0.22	0.07
SES index score	7.15	2.54	*	0.09	14.21	0.09	0.06
Always persistent	27.88	14.32	-	-11.89	67.64	0.26	0.06
Often persistent	27.92	11.84	-	-4.96	60.80	0.26	0.12
Rarely persistent	-3.61	12.32	-	-37.82	30.60	-0.03	-0.01
Sometimes persistent	14.74	10.78	-	-15.18	44.67	0.14	0.07
Year 1	29.69	7.77	*	8.11	51.27	0.28	0.10

Source: IELS assessment of 2,197 children, age 5, England

Table 31 Factors related to emotion identification, including gross motor skills

Parameter	Estimate	Standard error	Sig.	Min.	Max.	Effect Size Mean	Standardised Coefficient
Base case							
School variance	740.54	185.67	*	225.04	1256.03	-	-
Pupil variance	8512.35	355.47	*	7525.43	9499.28	-	-
Final model							
School variance	701.27	152.73	*	277.22	1125.32	-	-
Pupil variance	6275.44	247.83	*	5587.37	6963.52	-	-
Reduction in pupil variance	-	-	-	-	**26.69%**	-	-
Constant	-26.68	53.35	-	-174.80	121.44	-	-
Not at all distracted	45.80	12.36	*	11.50	80.11	0.48	0.24
Not really distracted	33.20	10.61	*	3.74	62.67	0.35	0.16
Distracted to some degree	24.68	10.86	-	-5.48	54.83	0.26	0.11
Not at all on task	-69.41	18.71	*	-121.37	-17.45	-0.72	-0.09
Not really on task	-32.94	10.70	*	-62.66	-3.22	-0.34	-0.08
On task to some degree	-4.38	6.54	-	-22.54	13.79	-0.05	-0.02
Have a back-and-forth conversation 1-2 days in a week	37.10	12.31	*	2.92	71.27	0.39	0.14
Have a back-and-forth conversation 3-4 days in a week	27.81	10.85	-	-2.32	57.94	0.29	0.13
Have a back-and-forth	36.54	10.82	*	6.49	66.60	0.38	0.19

Parameter	Estimate	Standard error	Sig.	Min.	Max.	Effect Size Mean	Standardised Coefficient
conversation 5-7 days in a week							
Up to 10 books	10.97	23.33	-	-53.80	75.75	0.11	0.03
11-25 books	32.72	26.41	-	-40.59	106.04	0.34	0.11
26-50 books	17.06	24.92	-	-52.12	86.24	0.18	0.07
51-100 books	30.22	24.16	-	-36.85	97.28	0.31	0.14
More than 100 books	30.84	24.45	-	-37.03	98.72	0.32	0.14
Age	60.54	7.88	*	38.67	82.42	0.26	0.19
Boy	-22.85	4.54	*	-35.46	-10.24	-0.24	-0.12
Gross motor score	0.10	0.03	*	0.03	0.17	0.15	0.11
Pupil not eligible for FSM	13.21	5.57	-	-2.24	28.67	0.14	0.05
No SEN	34.48	7.30	*	14.22	54.74	0.36	0.12
Always persistent	38.82	15.06	-	-2.99	80.63	0.40	0.09
Often persistent	26.88	13.21	-	-9.80	63.56	0.28	0.12
Rarely persistent	6.39	12.78	-	-29.08	41.86	0.07	0.02
Sometimes persistent	19.37	11.83	-	-13.47	52.20	0.20	0.10

Source: IELS assessment of 2,197 children, age 5, England

NFER was contracted to carry out IELS in England on behalf of the Department for Education (DfE) and this report includes analysis of pupil administrative data from the DfE's national pupil database (NPD). However, the views expressed in this report are the authors' and do not necessarily reflect those of the DfE.

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