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Self-report measures of the home learning environment in large scale research: Measurement properties and associations with key developmental outcomes

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Self-report measures of the home learning environment in large scale research: Measurement properties and associations with key developmental outcomes

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Abstract

Favourable home learning environments (HLEs) support children's literacy, numeracy and social development. In large-scale research, HLE is typically measured by self-report survey, but there is little consistency between studies and many different items and latent constructs are observed. Little is known about the stability of these items and constructs over time when used in either longitudinal research or studies with children with a wide range of ages. A review of the literature shows commonalities and differences between approaches in research on HLE. When we tested the psychometric properties of a short-form measure of HLE with a Rasch Item-Response-Model using longitudinal data from over 1600 Australian families, there was support for two dimensions of HLE – formal and informal learning frequency. We found that this measure was stable over the transitional period from pre-K to school as well as between gender and family language background. There were small but significant associations between the HLE measures and cognitive and behavioural developmental outcomes. We recommend that other measures of HLE could be similarly validated to assess their suitability for use in longitudinal research on learning environments. Recommendations are made for the future development of measures of broader constructs of the HLE.

Keywords*:* Australian E4Kids study; Home Learning Environment (HLE); preschool children; Rasch Item-Response-Model; short-form measures; testing of invariance

Introduction

The learning environment that parents provide for their children has long been a focus of research (e.g. Bus et al. 1995; van Steensel et al. 2011), with family processes, such as the frequency of reading to a child or teaching numbers and letters, being predictors of children's cognitive development (e.g. Sénéchal and LeFevre 2002). The broader concept of the home learning environment (HLE) might not only be an important predictor of academic skills, but also could influence children's social and behavioural development (e.g. Sylva et al. 2008). A general definition and a common operationalisation of HLE, however, are still missing. When measuring

HLE, studies focus on different aspects including home literacy, home numeracy or a more-general overall learning environment (e.g. Melhuish et al. 2008; Niklas and Schneider 2013, 2014).

Although the development of measures has been a tradition in learning environment research, little work is published that advances a measurement model of HLE. One exception is the Home Observation for Measurement of the Environment instrument that proposes a multifaceted measure of the HLE (HOME; e.g. Linver et al. 2004). Most studies also used sum scores of raw data rather than applying a measurement model (e.g., the Rasch model) as a more robust and appropriate approach to constructing a composite measure of a scale representing learning environments (Cavanagh and Romanoski 2006; Waugh and Cavanagh 2002). Applying a measurement model also allows the consideration of the quality of individual items and their contribution to the underlying theoretical model.

This paper first provides a summary of the literature relating to measuring HLE in large-scale research. Subsequently, longitudinal data from a large-scale study are used to assess the psychometric properties of three conceptualisations of the underlying dimensions of HLE and to test their stability over time and across gender and language backgrounds with an Item-Response-Theory (IRT) approach. The predictive validity of the selected HLE measure for cognitive and behavioural outcomes of children is also reported.

Home learning environment and child outcomes

During their first years, children typically spend the majority of their time with families. Parents have a significant influence on children's development because they interact consistently with their children from birth. In studies assessing the impact of early childhood education and care (ECEC) programs (e.g. Sylva et al. 2008), the input of parents is first factored out as a powerful predictor of developmental outcomes. The broad concept of HLE, therefore, comprises all aspects that support children's development in the home and a particular focus is often given to children's mathematical and literacy competencies in the context of their family (Niklas 2015). Often the reading behaviour, the frequency with which children play games with a mathematical context, and formal teaching done by parents are taken into account. So, too, are the number of books at home or parental attitudes and expectations and their involvement and support.

In particular, before school entry, the HLE is known to be a good predictor of children's literacy and numeracy outcomes (e.g. Manolitsis et al. 2013; Niklas and Schneider 2013, 2014), although there is also evidence of the importance of HLE during adolescence (e.g. Marjoribanks 2003). HLE is also linked to later academic achievement through cumulative skill acquisition: a consistently positive HLE strengthens early skills that form the basis for later development through school education (Roberts et al. 2005). For instance, Sénéchal and LeFevre (2002) found that the home literacy environment explained variance in precursors of later reading achievement such as vocabulary and phonological awareness. In addition, a richer HLE is also associated with better behavioural development (e.g. Schmiedeler et al. 2014; Sylva et al. 2008).

Further evidence of the importance of HLE for child development comes from direct intervention studies. Meta-analyses focusing on family literacy programs in the context of the family revealed that small to medium effects of such programs on children's linguistic competencies (Sénéchal and Young 2008, van Steensel et al. 2011). There is also some evidence that home-based interventions can be successful in enhancing children's numeracy competencies (e.g. Niklas et al. in press a; Sheldon and Epstein 2005) and even children's general cognitive abilities (Niklas et al. in press b).

Aspects and dimensions of the home learning environment

Most studies confirm that cognitive aspects of HLE, such as learning stimulation or access to learning materials, are the best predictors of child outcomes, particularly literacy and numeracy competencies (e.g. Leventhal et al. 2004; Sylva et al. 2008). However, there are differences in the way in which researchers operationalise the various aspects of the cognitive HLE (cf. Gershoff et al. 2007; Leventhal et al. 2004, Melhuish et al. 2008; Schmiedeler et al. 2014). Almost all large-scale longitudinal studies use the frequency at which the child was read to as a key item. Most studies also assess: the number of children's books at home; how often the child is sung to; whether explicit teaching of letters or numbers occurs; whether the child visits the library; and whether the child plays board-, card- or dice-games or does art or craft activities. Items such as involving the child in everyday activities such as cooking, caring for a pet, watching TV, telling stories, 'messy' play, or doing outside activities such as walking, swimming or cycling are sometimes included. Items of theoretical interest, such as

the frequency of computer usage and participation in extra-cost activities, have only been assessed in very few studies (e.g. in the Early Childhood Longitudinal Study (ECLS), Tandon et al. 2011) and little is known about how they contribute to children's learning and development. All of these items relate to family-orchestrated child experiences that relate to children's literacy, numeracy or even creativity.

To date, no work has been done to compare how individual items within measures of HLE contribute to child development. However, there are some indications that active and interactive aspects of HLE (e.g., reading with a child) predict children's linguistic outcomes better than passive aspects (e.g., a child observing the reading or TV watching behaviour of his or her parents) (Burgess et al. 2002). Given that large-scale studies often have to be economical in terms of the number and frequency of surveys and survey items asked, it is timely to focus on the contribution and quality of items assessing the active aspects of the HLE.

An often-used approach to cluster HLE items is the differentiation of the dimension 'home literacy environment' from the dimension 'home numeracy environment'. Whereas aspects of the home literacy environment predict linguistic competencies (e.g. Hood et al. 2008; Rashid et al. 2005), the latter is more predictive of mathematical competencies (e.g. LeFevre et al. 2009; Niklas and Schneider 2014). Although there is evidence for the specificity of both constructs in some studies, the home literacy environment proved to be a better predictor of children's numeracy than the home numeracy environment (e.g. Anders et al. 2012). Therefore, some studies used a broadly-defined single-dimension construct consisting of mathematical and linguistic activities, such as the frequency of playing games with a number context or the frequency at which children were read to (Melhuish et al. 2008; Schmiedeler et al. 2014).

Aspects of HLE can also be divided into activities that include informal or incidental learning during everyday activities and formal parental teaching or instruction (LeFevre et al. 2009; Sénéchal and LeFevre 2002; Skwarchuk et al. 2014). For instance, Sénéchal and LeFevre (2002) showed that informal literacy learning that occurs during reading to a child or telling the child a story helped children to gain vocabulary and listening comprehension, whereas formal teaching of letters was associated with letter knowledge and phonological awareness. The same distinction can be made in a mathematical context, with formal instruction in number-specific skills such as printing numbers or counting objects being differentiated from activities that are informally related to numbers such as playing board or dice games or measuring while cooking (LeFevre et al.

2009). Formal home numeracy practices seem to support children's symbolic number system knowledge, whereas informal exposure to games with numerical content predicts children's non-symbolic arithmetic (Skwarchuk et al. 2014). Both dimensions, informal and formal learning experiences, seem to play a role in children's cognitive development.

Operationalisations of the home learning environment

Different operationalisations are used when assessing HLE, which can involve direct observation of the learning environment that a family provides (e. g. Roberts et al. 2005), questionnaires on parent knowledge about children's books or authors (e. g. Hood et al. 2008) or more-general surveys on relevant aspects such as the number of books in the household or how often parents read to their children or introduced them to numbers or letters (e. g. Niklas & Schneider, 2010, 2014; Rashid et al., 2005). The Home Observation for Measurement of the Environment (HOME) is the most complete conceptualisation of the HLE, including an observational and interview schedule of 55 items requiring approximately 1 hour to complete within the respondent's home. There are different versions of the HOME for children aged 0–2, 3–5, 6–9 and 10–14 years that are comprised of several subscales that include learning or language stimulation and physical environment (cf. Linver et al. 2004; Totsika and Sylva 2004).

However, because using expansive observation schedules such as the HOME can be too labor intensive for large-scale research, often short-form surveys or self-report measures are applied. Although there is some risk of social desirability bias, reliable data have been collected and high concordance demonstrated with other measures, such as knowledge about children's books or diary entries (Burgess 2002). The National Longitudinal Survey of Youth (NLSY) study by Chase-Lansdale and colleagues (1991) involved developing short forms of the HOME (yielding a total HLE scale, emotional support scale, and cognitive stimulation scale). The School Readiness in Children (SRK; e.g. Niklas and Schneider 2013, 2014) and Effective Provision of Pre-School Education (EPPE; e.g. Melhuish et al. 2008) involve their own self-report inventories. For instance, in EPPE, a single factor cognitive-oriented HLE scale comprising seven equally-weighted items was used to predict children's cognitive and behavioural outcomes. In the SRK project, 12 items were used to measure the home

literacy environment as a predictor of linguistic competencies of preschool children and three items were used as a measure of the home numeracy environment that predicted children's development of mathematical competencies in kindergarten and primary school.

Measurement invariance of the home learning environment

Despite all the research on HLE, little is known about measurement reliability and comparability between groups that differ in regard to age, sex or ethnicity. Some studies indicate that HLE seems to be relatively stable, at least for the preschool children for numeracy and literacy aspects (Aikens and Barbarin 2008; LeFevre et al. 2009). However, despite considerable stability over the preschool age, the overall quality level of HLE seems to rise as children getting closer to school entry (Son and Morrison 2010). In addition, Rodriguez and Tamis-LeMonda (2011) showed that the development of HLE can differ greatly for individual families. Even more differences in the significance of individual HLE items can be expected between kindergarten and primary-school children. The HOME takes this into account by introducing different measures for children belonging to different age groups (cf. Linver et al. 2004). However, in longitudinal research, often the same items are used as repeated measures.

Individual child factors such as gender can also can generate unwanted variation in measures of HLE. Some studies revealed no difference in scores for HLE items between boys and girls and others found differences for the relationship between HLE and cognitive competencies in regard to gender (Bradley et al. 1987; Bradley et al. 1988; Marjoribanks 2003). There are also findings that parenting is important and that child competencies differ between different ethnic groups (Raver et al. 2007). It is timely, therefore, to analyse measures of HLE in regard to invariance between different subgroups by applying Rasch measurement before using them in longitudinal research.

Research focus

This study aimed to validate a robust short-form self-report measure of the HLE with an IRT approach using 12 items adapted from the ECLS (e.g. Gershoff et al. 2007) and addresses the following questions:

1. Are the 12 HLE items measuring a latent construct (i.e. HLE) and are they invariant over children's age, sex and main language?
2. What is the optimal dimensional structure given three hypothesised theorisations:
    a. An uni-factor model (e.g., the ECLS model)
    b. A two-factor model (i.e., informal versus formal learning frequency)
    c. A three-factor model (i.e., literacy, numeracy and creativity)?
3. What are the associations of the different HLE conceptualisations with language background and child characteristics and outcome measures?

A prior analysis of the data used in this paper involved exploratory and confirmatory factor analyses for 11 items in the main caregiver survey (Davis 2014). This yielded a 2-factor solution of 10 items (8 items for unstructured home activities; 2 items for structured activities; 1 item did not load). Our alternative conceptualisations (1-, 2-, and 3-factor models) used all 12 survey items and an Item Response Modelling approach to evaluate our models. Our 2-factor model uses the same conceptualisation as the 2-factor model proposed by Davis (2014) because this kind of differentiation of 'informal learning' and 'formal teaching' was proposed previously by other researchers (LeFevre et al. 2009; Senechal and LeFevre 2002; Skwarchuk et al. 2014).

Methods

Sample

We analysed results from an Australian large-scale longitudinal study designed to explore the effects of early childhood education and care (ECEC) experiences on children's learning and development. In 2010, ECEC services were selected to participate in the study from two states. Regions within the states were selected to represent metropolitan, regional and remote areas. ECEC services were randomly sampled, stratified by

location, service type and socioeconomic status and with high- and low-socioeconomic status services intentionally oversampled to ensure adequate response rates. A more in-depth description of the study can be found in Tayler and colleagues (2013).

At the beginning of the study in 2010, 2494 children were recruited from these services (48% female). Children entering the study were approximately 3 to 4 years of age (M = 1293 days or 43 months, SD = 222 days or 7 months as at 01 January 2010) and they were followed longitudinally. In 2010 (t1), 2011 (t2) and 2012 (t3) the children were assessed with the same tests, and parents were asked to provide information on family characteristics.

All families for whom at least one answer to the questions on HLE was available were included in the analyses. This resulted in a sample size of N = 1686 of which 808 children were female (47.9%) and 251 children spoke another language than English at home (14.8%). Most of these children (52.6%) were between 4 and 5 years old when assessed for the first time, whereas about a third of children were younger than 4 years (34.2 %) and 13.2% were older than 5 years. It needs to be taken into account that children who dropped out because of missing data showed significantly lower cognitive performances (t-tests; $p < 0.05$).

HLE measure

The HLE measure comprised 12 items (see Appendix A) that ask parents about active and salient aspects of HLE identified above (cf. Burgess et al. 2002), such as frequency of reading to the child, telling stories, playing games, music or teaching letters and numbers. In addition, two novel items (adapted from ECLS) were introduced – computer usage and participation in extra-cost activities.

Outcome variables

As a measure of cognitive outcome, two subtests of the Woodcock-Johnson III (WJIII) were applied. WJIII is a normed, validated measure of cognition and achievement (Mather and Woodcock 2001) based on the Cattell-Horn-Carroll (CHC) theory of multiple intelligences, made up of a hierarchy of narrow abilities, clustered

within broad abilities (Schneider and McGrew 2012). WJIII is designed to be used with participants from the age of 2 and up to 90 years. It is frequently used as an instrument to measure children's achievement (e.g. Howell and Kemp 2010).

Children's verbal competence and language development were assessed with the WJIII cognitive performance cluster Verbal Ability. This subscale measures vocabulary and language development in the form of spoken-language skills that do not require reading. The scale is measured by Picture Vocabulary (e.g. identify the picture of a horse from a set of pictures), Synonyms (e.g. another word for "angry"?), Antonyms (e.g. the opposite of "no"?) and Verbal Analogies (e.g. "eye is to see, as ear is to…"). Reliability of the Verbal Ability cluster is 0.94 for respondents between ages 5 and 19 (Mather and Woodcock 2001).

The WJ III Applied Problems subtest evaluates the participant's ability to analyse and solve mathematical problems by identifying an appropriate strategy and calculating the answer (Mather and Woodcock 2001). For example, when presented with pictures of three flowers in a row, with different numbers of bees on each flower, the researcher asks: "Put your finger on the flower with three bees." For children age four to six years, estimated reliabilities on this subtest range from 0.88 to 0.94 (Mather and Woodcock 2001).

Although no reliability data are reported for the two subtests in the technical manuals, both subtests are identified as age-appropriate (Mather and Woodcock 2001). For all tests we used the W score, a Rasch (like) scale that places all participants on a single continuous scale reflecting individual ability at the child's age (in months) as a function of the difficulty of the items that they answer correctly. A more in-depth discussion of the use of WJ III with preschool children in this study, their observed developmental trajectories, and stability over time can be found in Tayler and colleagues (2015).

In addition to these cognitive tests, the Strengths and Difficulties Questionnaire (SDQ; Goodman 1997) was used to ask parents about children's hyperactivity levels (5 items). It is a brief screening instrument for 3 to 16 year-olds. Higher scores indicate a higher level of hyperactivity and inattention (Cronbach's $\alpha = 0.78$).

Overview of statistical analyses

Measurement model

A Rasch Partial Credit -Model (Masters 1982) was used to define, calibrate and evaluate the HLE construct. The items that are indicators of HLE are hypothesised to be located at different 'difficulty' levels on the underlying construct continuum. The fact that items and individuals are located along a construct continuum and that the levels on the construct continuum can be described is one of the advantages that an item-response-model analysis has in comparison with other forms of empirical calibration such as factor analysis (cf. Nguyen and Griffin 2013). The Rasch model is sample- and item-free in the calibration process and, as a result, missing data are unimportant for the purposes of defining the latent construct (Wright and Masters 1982). In comparison with using raw scores that mostly are nonlinear in learning environments research, the Rasch model approach provides a more appropriate treatment of data (Cavangh and Romanoski 2006).

Criteria for evaluation of the items measuring a latent construct

There are several aspects to consider when evaluating a set of items measuring a latent construct such as HLE, including whether a "discernible line of increasing intensity" (i.e. increasing difficulty) can be identified (Wright and Masters 1982, p. 90). This is related to the extent to which items are sufficiently spread out along the construct continuum. ConQuest (Wu et al. 2007), the software used in our analyses, produces a variable map that provides an image of how well items are sufficiently spread out to define distinct levels of a construct, thereby providing information on the reliability of item separation. In addition, the reliability index of person separation shows the extent to which the items can differentiate individual cases (here, the families) along the construct continuum (here, HLE).

All items are ordered along the construct continuum according to their thresholds: it must concur that higher levels of response category within each item are more difficult than lower levels. Another aspect to be considered is whether the items function similarly between groups that differ on various characteristics such as age, gender and family language background – commonly known as testing for measurement non-invariance or item differential functioning. One last aspect to be considered is whether the items work together to define a single construct of HLE or whether there are signs of multidimensionality (Wright and Masters 1982).

Data analysis steps

The following steps were undertaken to complete the analysis for this study:

1. Test a one-dimensional model for all data sets (t1, t2, and t3)
2. Conduct differential item functioning (DIF) analysis in regard to child age, gender and main language
3. Compare results with two- and three-dimensional models
4. Extract plausible values (PVs) for each family to analyse the association of the different HLE models with family background and child outcome measures (correlational and regression analyses)

Bayesian estimates from the empirical posterior distribution were used to impute five PVs for each participant, for each of the three conceptualisations of HLE. These PVs were analysed individually, as with other imputation frameworks, and the pooled results of these analyses are reported (von Davier et al. 2009).

Results

Descriptive statistics

Table 1 provides descriptive statistics for age of children at first testing and child outcomes. Children were about 4 years old at the study's commencement. Whereas they improved in the WJIII tests, parent ratings of hyperactivity remained relatively stable over time.

Insert Table 1 about here

One-dimensional model of HLE

The Rasch model was used to place the HLE items on an underlying scale, visualised by the variable map presented in Figure 1. On the left side of the map is the scale ranging from –1.5 to +1.5. This logit-scale

represents the logarithm of the odds of families having a HLE level at category k or higher (e.g., a probability of 0.5) rather than category k-1 for each item. The variable map also represents the estimates of families' HLE level, represented by Xs, and the difficulty of each HLE-item, represented by x.y notation on the right-hand side of the map. In each x.y notation, the x represents the item number (see Appendix A) and y represents the answer category (out of the 8 possible categories ranging from 0 to 7). For example, 5.3 indicates category 3 on item 5 (on 3 days within the last week the child has played board or card games with someone in the family). Figure 1 indicates that the 12 items formed several clusters that stand for different levels of family overall scores along the continuum of HLE. In addition, it shows that the set of items cover the overall HLE scores of families very well.

An item separation reliability index of 0.997 was estimated, indicating that the 12 items can be very well differentiated. The set of items also differentiated parents well with a person separation reliability index of 0.82. In addition, fit statistics of each HLE-item were calculated. In general, almost all items fit the model well, indicating high utility and validity of this measure of HLE (Wright and Masters 1982). Item 10 (Computer), however, showed an under-fit, indicating that this item might not function in the same way across the three years. Item 12 (Extra-cost activities) and item 10 (Computer) had very low discrimination indices but, because item 12 is a relatively difficult item (almost only low values are observed), its low discrimination can be accepted. Items 8 and 9 (teaching "letter and alphabet" resp. "numbers and shapes") showed over-fit. Whereas over-fit items often are valued for their high discrimination power, sometimes, this can be a signal that these items measure some construct different from the rest of the items.

Insert Figure 1 about here

Differential item functioning

In a next step, differential item functioning (DIF) for each item and group (differing in regard to age, main language or gender) was analysed. Because there is no general agreement on when DIF differences become important, strict cut offs were chosen with DIF effect sizes bigger than 0.3 or smaller than -0.3 as criterion

(Zwick et al. 1999). It should also be noted that even items that show great DIF effect sizes do not have to be biased, but the DIF rather could show a true difference between groups. Table 2 shows all items with a DIF effect size outside the defined range (DIFs of all items can be requested from the authors).

Insert Table 2 about here

In Table 2, the first column shows the groups that are compared and column 2 lists the items for which large DIF effect sizes were found (see column 7). Column 3 presents the difference in item difficulty between the whole sample and a certain subgroup. A negative value indicates that an item is easier for this subgroup in comparison to the whole sample (i. e. the activity was done more often). Column 4, 5 and 6 show statistics for the differences between the groups and the overall fit.

There were only four cases with substantive DIF effect sizes: item 10 (computer) and 12 (extra-cost activities) for age and item 1 (reading) and 6 (everyday activities) for home language. Given that children experience the same level of overall HLE, parents of older children are more likely to spend time with them for computer usage and for extra-cost activities outside the home. In addition, parents in English-speaking households were more likely to spend more time doing everyday activities such as cooking or caring for a pet and reading to their child than parents from non-English speaking backgrounds who provide the same overall level of HLE. No substantive DIF was found between boys and girls, although there was a tendency for girls with the same level of overall HLE to draw pictures more often (item 3, Effect size .28).

When comparing the different subgroups for each item, it became clear that the fit of item 10 (computer) was problematic. Fit was worse for children belonging to the youngest age groups, boys and children living in households speaking a language other than English. For the latter group, also a poor fit for item 12 (extra-cost activities) was observed. Overall there was adequate fit over each year of the study, indicating that the underlying scale was not affected significantly by child age.

Multidimensional models of HLE

Because the overall home learning environment is often differentiated into more specific dimensions, two more models were tested against the one-dimensional model. The two-dimensional model differentiated between children's formal learning guided by parents (items 8 and 9 in Appendix A) and informal learning that occurs during activities in and outside home (all other items), The three-dimensional model differentiated items that refer to the home literacy environment (items 1, 2, and 8 in Appendix A) and the home numeracy environment (items 5, 6, and 9), with items that refer to creative activities (all other items).

Insert Table 3 about here

The conceptualisations of HLE, overall model fit indices and items fit indices are presented in Table 3. The model with the best overall fit was the two-dimensional model. Furthermore, the person reliability index of model 2 was higher than the reliability index of the other competing models (0.81 for the one-dimensional model, 0.87 and 0.80 for dimension 1 and 2 for the two-dimensional model, and between 0.76 and 0.78 for the three-dimensional models). The two items on formal learning frequency (items 8 and 9) had an excellent fit. The correlations between the two dimensions was 0.7, whereas the correlation between the dimensions of the three-dimensional model were much higher ($r_{literacy/numeracy} = 0.90$; $r_{literacy/creativity} = 0.86$; $r_{numeracy/creativity} = 0.88$), indicating that the three-dimensions did not differentiate well for the 12 study items.

Correlational and regression analyses

In a subsequent analysis, PVs for all three models of HLE were calculated and used for analyses of the association of HLE with child characteristics, families' language background and child outcome measures. Table 4 provides the correlation matrix for all variables. All different conceptualisations of HLE were closely associated, with all inter-dimension correlations above $r = 0.65$. Significant, but very low, interrelations were noticed for HLE with sex, age and main language. Girls lived in a slightly more-positive overall HLE, whereas older children and children with a language other than English as main language experienced most HLE activities less often. In regard to behavioural and cognitive outcome measures, small and mostly significant

correlations were found for the HLE-dimensions. Lower and often nonsignificant values were found for Formal Learning and Applied Problems" and higher values were found for Hyperactivity (i.e. less symptoms), the overall HLE dimension and dimensions of Informal Learning and Home Literacy Environment.

Insert Table 4 about here

Regression analyses predicted child initial outcomes at t1 and the subsequent development until t3, while controlling for sex, age and home language. Results are presented for the two-dimensional model of HLE and here for informal learning only (all other results can be requested from the authors). Table 5 shows the results for the prediction of initial child outcomes.

As can been seen, informal learning was a significant predictor of all three child outcome variables, even when age, sex and child language were controlled for. About 1% to 2 % of additional variance was explained when this dimension of HLE was introduced into the regression model, indicating a small but meaningful effect. Children living in a more favourable HLE showed superior performance on cognitive tasks and fewer symptoms of hyperactivity/inattention.

Insert Table 5 about here

Table 6 shows the results of regression analyses to predict children's further development between t1 and t3 for informal learning. Model 1 includes the initial value of the outcome measure at t1, model 2 includes the control variables, and in model 3 informal learning was introduced. Again informal learning was a significant predictor of the development of the cognitive outcomes measured, but only about 1% of variance was explained. In regard to hyperactivity only a nonsignificant tendency was found, with a favourable HLE reducing these symptoms.

Insert Table 6 about here

Finally, a moderator effect of home language was found. For children, who spoke English at home, a more favourable home learning environment led to both greater initial verbal comprehension and greater growth. In comparison, children who spoke a language other than English at home had a lower level of verbal comprehension at t1 when they experienced a more favourable HLE ($p < 0.05$ for the interaction term 'informal learning * main language'). However, this disadvantage was nullified by a much steeper growth in verbal comprehension between t1 and t3 for these children ($p < 0.05$ for the interaction term 'informal learning * main language').

When running these analyses with the other conceptualisations of HLE, all dimensions were significant predictors of initial outcomes, with the exception of "formal learning" being only a marginally significant predictor of Applied Problems ($p < .10$). Concurrently, for "informal learning", all other conceptualisations of HLE were significant predictors of cognitive development, but not of the development of symptoms of hyperactivity.

Discussion

There are clear indications that HLE plays an important role in child development and interventions that target families and try to enrich HLE are successful in supporting children's competency development (e.g. Niklas et al. in press a,b: Niklas and Schneider 2013, 2015; Sheldon and Epstein 2005; van Steensel et al. 2011). However, few studies have considered the underlying construct of HLE and identified important aspects of the home environment that influence children's development. This study analysed and compared different conceptualisations of HLE to extend the use of frequently-used survey items and progress towards a more psychometrically-sound concept of the HLE. IRT was used as a robust approach to measurement in education and developmental psychology, particularly in the context of learning environments research (Cavanagh and Romanoski 2006; Waugh and Cavanagh 2002; Wright and Master 1982).

Our results show that the hypothesised measurement model held up and was empirically supported. The individual items behaved well in the model: thresholds increased incrementally with the item scale. The overall model fit was excellent for 11 of the 12 items in all three conceptualisations. The item map illustrates that the

observed families were distributed around the middle of the scale and that the items covered the range well, providing good discrimination and targeting information.

Two items, computer usage and extra-cost activities, showed lower discriminative power, lower fit and differed in their functioning between children of different age groups. While their inclusion in the model was sound, in future work, these items and other additional items must be thoughtfully considered, rather than assuming functioning across age ranges. Alternatively, such items could be included only in measures of HLE for older children for whom they showed better properties – an approach similar to the HOME that changes items to fit well with the age range of interest (Linver et al. 2004).

DIF was found for the items "reading to children" and "everyday activities" for children with a main language other than English. Because reading high-quality material to children is an essential part of a positive home learning environment (e.g. Lonigan 1994), this warrants attention when planning interventions in families having a main language other than English. Apparently, even when parents from non-English speaking backgrounds provided higher overall HLEs, they tended to read less often to their children and were less likely to spend time together with their child (e.g., in activities like cooking or caring for a pet). An influence of a background of migration was also found in former studies (e.g. Niklas and Schneider 2013), though not necessarily in an Australian context (Niklas et al. 2015). Of interest in this context is the finding that the child's main language acted as a moderator for children living in a more favourable HLE. Speaking a language other than English indicated lower initial verbal comprehension, but a much steeper growth, in comparison to children also speaking a language other than English but experiencing a less favorable HLE. These findings warrant further investigation. Using English to assess these children's outcomes, while activities they experience in the HLE are in a different language, might partly explain these results.

There was empirical support for the two-dimensional model (formal vs. informal learning frequency) because it fitted the data best (cf. Sénéchal and LeFevre 2002; Skwarchuk et al. 2014). This conforms to early educational approaches that highlight the importance for children experiencing both adult-led and informal learning experiences, such as the Victorian Early Years Learning and Development Framework (DEECD 2009). Studies should therefore try to include measures for both of these aspects because they are reliable predictors of child competencies (e.g. LeFevre et al. 2009; Sénéchal and LeFevre 2002). The three-dimensional model, in

comparison, clearly seems not to be the best choice: the overall fit was worse and all three dimensions were highly correlated, indicating that they cannot be well differentiated from each other with the items used.

In the correlational and regression analyses, the different conceptualisations of HLE proved to be significantly associated with child outcomes and meaningful predictors of the outcomes. These findings confirm former research, showing that different operationalisations and approaches to measuring HLE lead to comparable results (Burgess 2002). Moreover, the results of this study align with results of other researchers who used shorter questionnaires to measure the home learning environment and predict children's cognitive and behavioural outcomes (e.g. Melhuish et al. 2008; Schmiedeler et al. 2014).

That Formal Learning Frequency was only weakly associated with initial child outcomes might be attributable to the fact that this conceptualisation of HLE only consisted of 2 items. However, the correlations with child outcomes became more profound over time and "formal learning frequency" was a significant predictor of the development of children's cognitive abilities. This aligns with results from earlier studies indicating that such activities might be of greater importance for later developing skills (e.g. Sénéchal and LeFevre 2002).

Limitations

The measure used in the current study comprised of 12 items and was focused on the frequency of activities and behaviours in the home. Given the modest correlations between the identified HLE constructs and children's outcomes, future research should include additional items such as the presence of books, games and other learning materials. For instance, the number of books in a household has proved to be a good predictor of children's linguistic competencies in earlier work (e.g. Niklas et al. 2013). Depending on the focus of a study, it also might be useful to concentrate on specific domains rather than on more general conceptualisations of HLE (e.g. LeFevre et al. 2009; Niklas and Schneider 2013).

Only small effects sizes were found in our analyses. While this was to be expected (e.g. van Steensel et al. 2011), they were still lower than in other studies (e.g. Melhuish et al. 2008; Niklas and Schneider 2013). This indicates that our items perhaps covered a different subset of the home environment. In addition, no measures of

the learning environments provided in the context of early childhood education and care programs or schools were included in the analyses.

Only data from families for whom at least one answer to the questions of HLE were available was included in the analyses. This led to a large drop-out rate for children who showed significantly lower cognitive performances ($p < 0.05$). Consequently, the results have to be interpreted carefully.

Strengths

This study also has several strengths. We were able to use a longitudinal approach with data from a large and representative Australian sample. The age of the children in our sample varied over the assessments from between 2 and 7 years, thus covering an important developmental period and the life-phase in which HLE seems to be of upmost importance (Hood et al. 2008; Sénéchal and LeFevre 2002). We found evidence that dimensions of the HLE are non-invariant over child age – an important discovery for researchers interested in measuring aspects of the family home environment in studies including a broad range of ages.

In addition, standardised and well-known outcome measures were assessed, enabling us to compare different aspects of HLE in regard to how well they predict cognitive and behavioural competencies of children. We demonstrated a significant cross-sectional association between HLE and child competencies. We found HLE to be a predictor in longitudinal analyses, while controlling for initial outcome, age, sex and home language. Furthermore, we used a Rasch model to check the HLE test instrument, testing for differential item functioning and assessing fit for different conceptualisations of HLE. Consequently, our robust approach further advanced the measurement of the HLE and should be applied more often in the context of learning environments research (Cavanagh and Romanoski 2006).

Conclusion

The HLE is an important predictor of children's cognitive and behavioural outcomes. However, there is still no commonly-used definition and operationalisation of this construct. Many large-scale studies use their own short-

report measures of HLE with items varying between studies according to the individual research focus. Little work on measurement properties has been conducted. Here, a 12-item scale of HLE was thoroughly analysed using item-response-theory. Findings were in favour of a two-dimensional conceptualisation of HLE, differentiating between formal and informal learning frequency. These dimensions align well with the literature and are a robust conceptualisation of HLE. However, other conceptualisations of HLE, such as global HLE or specific measures of the home literacy or home numeracy environment, were also related to children's cognitive and behavioural outcomes. Consequently, depending on the specific focus of studies, there is justification for focusing on broader or more specific aspects of HLE that are theoretically linked to the outcomes measured. Ongoing psychometric work is likely to build greater consensus concerning the underlying elements of the HLE. This will add to our understanding of the factors underpinning the HLE, their stability over time and across subgroups, their relationship to outcomes across developmental domains, and their relationship to other learning environments.

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Appendix A

Questionnaire on HLE Used in the E4Kids Study

Tell us about the study child's experiences at home

In the last week, on how many days have you or someone in your family done the following with the study child:

		Days							
		0	1	2	3	4	5	6	7
1)	Read to the study child from a book?								
2)	Told the study child a story, not from a book?								
3)	Drawn pictures or done other art or craft activity?								
4)	Played music, sang songs, danced, or done other musical activity with the study child?								
5)	Played with toys or games inside like board or card games with the study child?								
6)	Involved child in everyday activities like cooking or caring for a pet?								
7)	Played games outside together like walking, swimming or cycling?								
8)	Done activities with the study child that helped them learn letters or alphabet?								
9)	Done activities with the study child that helped them learn numbers and shapes?								
10)	Done activities using a computer such as a computer game or internet search?								
11)	Done activities at home that are messy, like painting?								
12)	Taken the study child to a special or extra-cost activity outside of the home, like ballet, gymnastics, swimming or language lessons?								

List of figures

Fig. 1 Variable map of the twelve HLE-items (Rasch model)

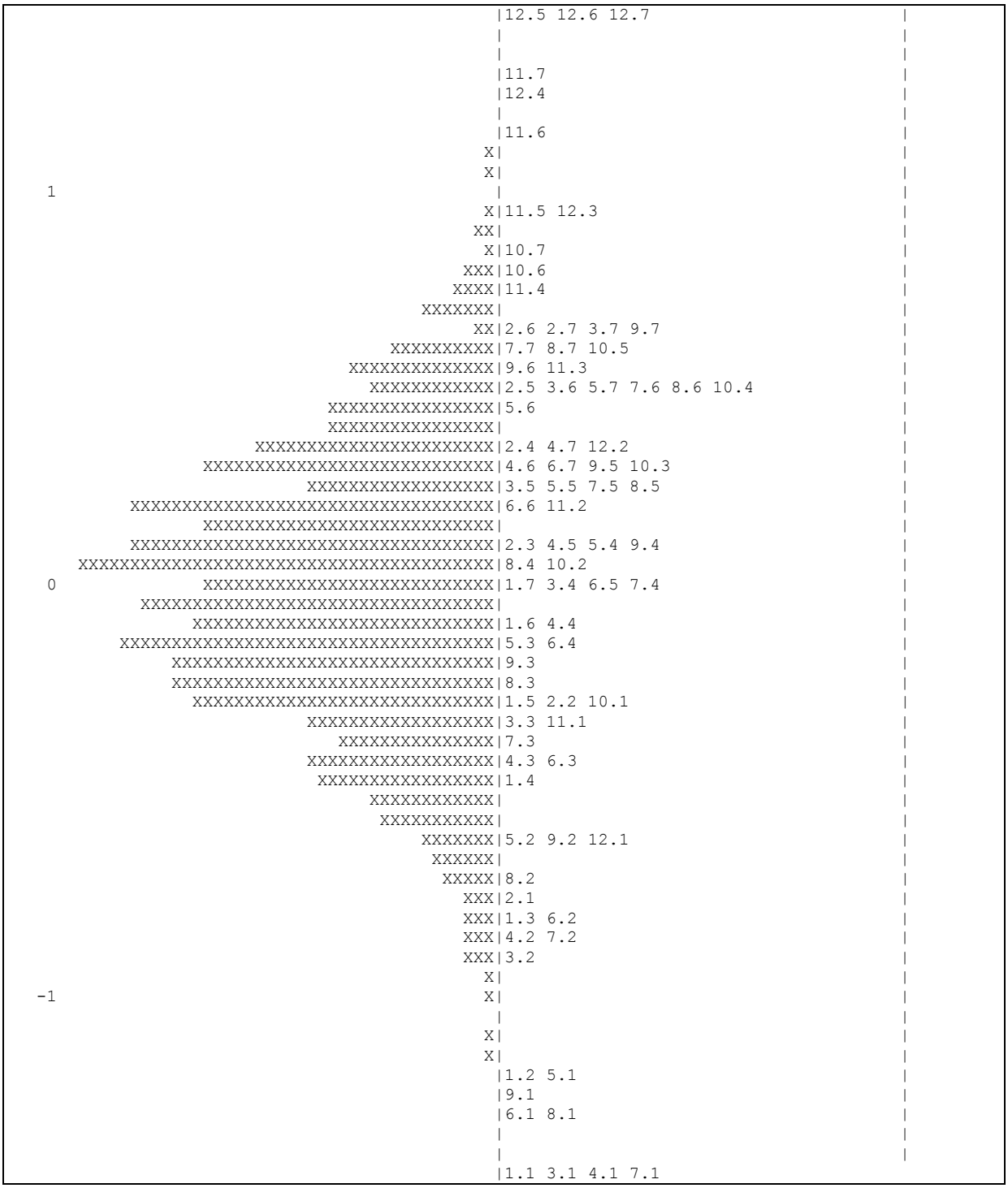

12.5 12.6 12.7
11.7
12.4
11.6
1
11.5 12.3
10.7
10.6
11.4
2.6 2.7 3.7 9.7
7.7 8.7 10.5
9.6 11.3
2.5 3.6 5.7 7.6 8.6 10.4
5.6
2.4 4.7 12.2
4.6 6.7 9.5 10.3
3.5 5.5 7.5 8.5
6.6 11.2
2.3 4.5 5.4 9.4
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0
1.7 3.4 6.5 7.4
1.6 4.4
5.3 6.4
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8.3
1.5 2.2 10.1
3.3 11.1
7.3
4.3 6.3
1.4
5.2 9.2 12.1
8.2
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1.3 6.2
4.2 7.2
3.2
-1
1.2 5.1
9.1
6.1 8.1
1.1 3.1 4.1 7.1

Fig. 1

Table 1 Descriptive statistics for age and child outcomes

Outcome	*N*	Min	Max	*M*	*SD*
Age at testing (t1)	1532	25	72	48.17	6.86
Hyperactivity_t1	1647	0	10	3.37	2.45
Hyperactivity_t2	1238	0	10	3.17	2.45
Hyperactivity_t3	897	0	10	3.15	2.51
Verbal Ability_t1	1460	407	495	452.06	13.38
Verbal Ability_t2	1405	407	499	461.45	14.00
Verbal Ability_t3	1343	424	511	473.62	13.43
Applied Problems_t1	1457	318	526	398.28	24.87
Applied Problems_t2	1431	318	502	416.69	20.87
Applied Problems_t3	1363	318	526	438.53	20.01

Table 2 DIF analyses, item difficulties, test statistics, overall fit and effect sizes of HLE-items in regard to child age, gender and home language

DIF*	Items	Difference	SE	*t*	Weighted MNSQ	Effect size
Age group 1	Computer	0.151	0.001	151.00	1.38	0.46
Age group 2	Computer	-0.004	0.002	-2.00	1.2	-0.01
Age group 3	Computer	*-0.147*	0.001	-147.00	1.21	-0.44
Age group 1	Extra-cost_activities	*0.156*			1.11	0.47
Age group 2	Extra-cost_activities	*0.023*	0.007	3.29	1.1	0.07
Age group 3	Extra-cost_activities	*-0.179*	0.008	-22.38	1.11	-0.54
Non-English	Reading	0.10	0.003	33.33	1.02	0.30
English	Reading	*-0.10*	0.003	-33.33	1.07	-0.30
Non-English	Everyday_activities	0.12	0.004	30.75	1.16	0.37
English	Everyday_activities	*-0.12*	0.004	-30.75	1.01	-0.37

* Age group 1 = 2 to 4 years; age group 2 = 4.01 to 5 years; age group 3 = older than 5 years

Table 3 Different conceptualisations of HLE, overall model fit and item fits

Item	1 dimension		2 dimensions		3 dimensions	
Item 1: (Reading)	HLE	1.10	Indirect learning	1.06	Literacy	1.14
Item 2: (Tell_story)	HLE	1.00	Indirect learning	0.97	Literacy	1.04
Item 3: (Draw_pictures)	HLE	0.92	Indirect learning	0.9	Creativity	0.9
Item 4: (Play_music)	HLE	0.94	Indirect learning	0.92	Creativity	0.92
Item 5: (Board or card games)	HLE	1.00	Indirect learning	0.97	Numeracy	1.08
Item 6: (Everday_activities)	HLE	1.06	Indirect learning	1.03	Numeracy	1.12
Item 7: (Games_outside)	HLE	0.98	Indirect learning	0.94	Creativity	0.94
Item 8: (Letters_alphabet)	HLE	0.85	Direct Teaching	1.01	Literacy	0.89
Item 9: (Numbers_shapes)	HLE	0.84	Direct Teaching	1.02	Numeracy	0.88
Item 10: (Computer)	HLE	1.34	Indirect learning	1.27	Creativity	1.25
Item 11: (Messy_activities)	HLE	0.90	Indirect learning	0.88	Creativity	0.89
Item 12: (Extra-cost_activities)	HLE	1.12	Indirect learning	1.11	Creativity	1.1
Deviance	70827.57		69787.56		70869.57	

Table 4 Correlations between different HLE models, child characteristics, home language and child outcomes

	Correlations																
	Dir l	Ind l	Lit	Num	Crea	sex	age	H lan	Hyp t1	Hyp t2	Hyp t3	VA t1	VA t2	VA t3	AP t1	AP t2	AP t3
HLE	0.673**	0.795**	0.777**	0.789**	0.782**	0.055*	-0.054*	-0.067*	-0.138**	-0.131**	-0.147**	0.081**	0.077**	0.103**	0.049	0.028	0.064*
Formal learning		0.693**	0.680**	0.684**	0.645**	0.020	-0.035	-0.018	-0.072**	-0.059*	-0.078*	0.065**	0.062*	0.084**	0.029	0.037	0.077**
Informal learning			0.765**	0.768**	0.778**	0.042	-0.056*	-0.057*	-0.125**	-0.117**	-0.128**	0.077**	0.076**	0.104**	0.040	0.035	0.056
Literacy				0.900**	0.859**	0.045	-0.065*	-0.069*	-0.136**	-0.118**	-0.136**	0.088**	0.087**	0.122**	0.063*	0.037	0.072**
Numeracy					0.881**	0.037	-0.064*	-0.066*	-0.136**	-0.119**	-0.132**	0.070*	0.071*	0.101**	0.045	0.029	0.056*
Creativity						0.057	-0.042	-0.053	-0.139**	-0.137**	-0.144**	0.073**	0.078**	0.107**	0.048	0.039	0.064*
Sex #							0.009	0.020	-0.127**	-0.166**	-0.170**	0.027	0.029	0.026	0.086**	0.061*	0.013
Age								0.007	-0.064**	-0.037	-0.012	0.456**	0.463**	0.409**	0.463**	0.460**	0.523**
Home lang									-0.018	-0.033	-0.009	-0.205**	-0.211**	-0.183**	-0.166**	-0.155**	-0.081**
Hyperactivity t1										0.725**	0.643**	-0.153**	-0.130**	-0.164**	-0.149**	-0.166**	-0.182**
Hyperactivity t2											0.690**	-0.151**	-0.143**	-0.157**	-0.198**	-0.205**	-0.178**
Hyperactivity t3												-0.133**	-0.168**	-0.165**	-0.199**	-0.203**	-0.217**
Verbal Ability t1													0.701**	0.664**	0.674**	0.580**	0.569**
Verbal Ability t2														0.723**	0.651**	0.662**	0.606**
Verbal Ability t3															0.620**	0.628**	0.662**
Appl Prob t1																0.700**	0.611**
Appl Prob t2																	.688**

** $p < 0.01$, * $p < 0.05$; # 0 = boys; 1 = girls; Home lang = Home language (0 = only English; 1 = another language); Appl Prob = Applied Problems

Table 5 Results of hierarchical regression analyses predicting hyperactivity, Verbal Ability and Applied Problems at t1

Variable	Unstandardised regression coefficient *b*	SE	*t*	Explained variance R^2	Gain Δ R^2 by HLE
Hyperactivity					
Model 2				0.04***	0.02***
Age	-0.028	0.10	-2.89**		
Sex #	-0.59	0.12	-4.95***		
Child language +	-0.25	0.28	-0.90		
Informal learning	-0.92	0.18	-5.08***		
Verbal ability					
Model 2				0.26***	0.01***
Age	9.87	0.49	20.20***		
Sex #	0.62	0.61	1.03		
Child language +	-12.84	1.42	-9.04***		
Informal learning	3.64	0.96	-3.79***		
Applied problems					
Model 2				0.25***	0.00*
Age	18.69	0.91	20.52***		
Sex #	4.14	1.13	3.67***		
Child language +	-19.69	2.66	-7.41***		
Informal learning	3.95	1.72	2.30*		

* $p < 0.05$; ** $p < 0.01$; *** $p < 0.001$

0 = boys; 1 = girls

+ 0 = English is child's only language; 1 = another language than English is spoken at home

Table 6 Results of hierarchical regression analyses predicting development of hyperactivity, Verbal Ability and Applied Problems between t1 and t3

Variable	Unstandardised regression coefficient *b*	SE	*t*	Explained variance R^2	gain Δ R^2 by HLE
Hyperactivity t3					
Model 3				0.42***	0.00
Hyperactivity t1	0.64	0.03	24.08***		
Age	0.11	0.10	1.01		
Sex #	-0.44	0.13	-3.44**		
Child language +	0.01	0.30	0.03		
Informal learning	-0.33	0.23	-1.44		
Verbal ability t3					
Model 3				0.46***	0.01**
Verbal ability t1	0.61	0.03	23.15***		
Age	3.37	0.55	6.08***		
Sex #	0.20	0.61	0.33		
Child language +	-4.05	1.46	-2.78**		
Informal learning	2.67	1.10	2.43*		
Applied problems t3					
Model 3				0.45***	0.00*
Applied problems t1	0.39	0.02	18.74***		
Age	10.49	0.83	12.64***		
Sex #	-1.37	0.91	-1.50		
Child language +	-0.14	-2.17	-0.01		
Informal learning	3.55	1.75	2.12*		

* $p < .05$; ** $p < .01$; *** $p < .001$

0 = boys; 1 = girls

+ 0 = English is child's only language; 1 = another language than English is spoken at home