Published in final edited form as:

Learn Individ Differ. 2013 December ; 28: 133–141. doi:10.1016/j.lindif.2012.06.011.

Dimensionality and Reliability of Letter Writing in 3- to 5-Year-Old Preschool Children

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Abstract

The primary purpose of this study was to examine the dimensionality and reliability of letter writing skills in preschool children with the aim of determining whether a sequence existed in how children learn to write the letters of the alphabet. Additionally, we examined gender differences in the development of letter writing skills. 471 children aged 3 to 5 years old completed a letter writing task. Results from factor analyses indicated that letter writing represented a unidimensional skill. Similar to research findings that the development of letter-names and letter-sound knowledge varies in acquisition, our findings indicate that the ability to write some letters is acquired earlier than the ability to write other letters. Although there appears to be an approximate sequence for the easiest and most difficult letters, there appears to be a less clear sequence for letters in the middle stages of development. Overall, girls had higher letter writing scores compared to boys. Gender differences regarding difficulty writing specific letters was less conclusive; however, results indicated that when controlling for ability level, girls had a higher probability of writing a letter correctly than boys. Implications of these findings for the assessment and instruction of letter writing are discussed.

Keywords

Alphabet knowledge; Assessment; Letter writing; Literacy; Preschool

Alphabet knowledge — knowledge of letter names and letter sounds has repeatedly been shown to be one of the best predictors of reading skills (e.g., Lonigan, Schatschneider, & Westberg, 2008; Schatschneider, Fletcher, Francis, Carlson, & Foorman, 2004). Thus, knowledge of letter names and letter sounds is considered an important emergent literacy skill and an essential part of learning a writing system. In addition to letter names and letter sounds, which are important for learning to read, learning to write letters must also play an important part in the acquisition of early literacy skills. At the very least, one needs to write letters to be able to write anything. To date, however, research efforts have focused on examining the development of letter-name and letter-sound knowledge with much less attention devoted to understanding the development of letter writing.

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Background and context

Research with children in grade school indicates that the ability to write the letters of the alphabet fluently constrains their ability to spell words and to produce written text (e.g., Berninger, Mizokawa, Bragg, Cartwright, & Yates, 1994; Graham, Berninger, Abbott, Abbott, & Whitaker, 1997). When children have to devote their cognitive resources to forming the letters of the alphabet, they have fewer resources for higher-order writing tasks such as composing (McCutchen, 1996). More recent evidence indicates that children's ability to write the letters of the alphabet plays a significant role even before grade school (Puranik & Al Otaiba, 2012; Puranik, Lonigan, & Kim, 2011); from the time children first begin or learn to write. Recently Puranik et al. reported that children's letter writing contributed significantly to their spelling (an early writing skill) after accounting for their letter-name and letter-sound knowledge, print concepts, and name writing skills. One reason that letter writing may be important is because it serves as a proxy for children's emerging orthographic knowledge (Puranik & Apel, 2010; Ritchey, 2008). Orthographic knowledge has been shown to make important contributions to spelling and writing in beginning writers (e.g., Apel, Wolter, & Masterson, 2006; Berninger, Abbott, Nagy, & Carlisle, 2010; Ouellette & Sénéchal, 2008), leading researchers to acknowledge its important role in the development of literacy skills (see Apel, 2009 and Berninger et al., 2010 for reviews).

Research on the development of alphabet knowledge indicates that children do not develop knowledge about all letters simultaneously. Rather, some letter names and letter sounds are easier and hence learned before others (e.g., Justice, Pence, Bowles, & Wiggins, 2006; McBride-Chang, 1999; Petscher & Kim, 2011; Phillips, Piasta, Anthony, & Lonigan, 2012; Treiman & Kessler, 2003), indicating that specific letter-name and letter-sound knowledge varies in acquisition. For example, children learn the name and sound for the letter B earlier and more easily than for the letter F (Treiman & Kessler), and children learn the first letter of their names before other letters (Phillips et al., 2012; Treiman & Broderick, 1998). Similarly, children may learn to write some letters before others, and preliminary evidence seems to suggest that this might be the case. Pollo, Kessler, and Treiman (2009) undertook a study to determine if there were patterns in preschool children's early spelling attempts by comparing the spelling of children from Brazil and from the U.S. They reported that the letters children used in their early attempts to spell words were not random. Rather, the letters used reflected the frequencies of the letters in the language to which the child was exposed. Thus, it is plausible that, similar to the acquisition of letter-name and letter-sound knowledge, children's letter-writing skill also varies in acquisition. This variability in development has important implications for the assessment and teaching of letters and, hence, should be considered by both researchers and educators.

A sizeable body of research on children's learning of the lowercase letters of the alphabet exists (see Graham & Weintraub, 1996 for a review). Although the methods for collecting letter-writing samples among studies have varied from asking children to copy the letters of the alphabet (e.g., Lewis & Lewis, 1964), comparing lowercase letters written in manuscript versus cursive style (e.g., Newland, 1932; Pressey & Pressey, 1927), writing letters to dictation (e.g., Ritchey, 2008), to asking children to write letters from memory (Graham, Weintraub, & Berninger, 2001), the results generally indicate that letters vary in their relative difficulty. However, because different methods have been used to collect letterwriting samples, results have also varied a little between studies. For example, Lewis and Lewis (1964) reported that the letters l, o, i, v, and c were generally easier to write for first grade children whereas the letters q, z, u, j, and k were considered relatively difficult. Graham et al. (2001) reported that the letters c, e, s, i, o, v, and x were relatively easy for first grade children whereas the letters q, z, g, d, n, j, k, and u were the most difficult.

Most of this previous work has involved examining the lowercase letter-writing skills in grade school children from first grade and beyond. However, there have been a few studies examining letter writing in children younger than first grade. One exception was a study by Ritchey (2008), in which kindergarten children’s skills at writing both uppercase and lowercase letters was examined. The uppercase letters that were the easiest for kindergarten children to write were A, O, X, L, whereas the letters that were the most difficult for them to write were Z, C, J, Q, and G. Preschool children’s letter writing has been examined in two previous studies. Coleman (1970) examined the lowercase writing skills of 10 preschool children. Worden and Boettcher (1990) examined uppercase and lowercase letter writing in 188 preschool and elementary school children who ranged in age from 4 to 7 years. Children were asked to write letters from memory. The easiest letters for the 4-year-old children were O, A, H, L, T, and I, and the easiest letters for the 5-year-old children were O, A, T, X, C, and F. Children in both age groups had difficulty writing the letters D, G, J, Y, and Z.

Children first learn to write in preschool, and they first learn to write letters in uppercase before they learn to write lowercase letters — perhaps because lowercase letters are more difficult to write than uppercase letters (e.g., Stennett, Smythe, Hardy, & Wilson, 1972). Young children show a preference for writing in uppercase letters (Bissex, 1980; Treiman & Kessler, 2004). This preference is reflected in their performance; children, ages 4 through 6 years have better performance on uppercase letters than on lowercase letters (Treiman & Kessler; Worden & Boettcher, 1990). It is not clear when proficiency in letter writing develops, and we do not know the sequence in which letters are learned because it has not been examined prior to school entry. In the two studies mentioned above that involved preschool children, one examined lowercase writing abilities (Coleman, 1970), and the other provided descriptive data and was completed over two decades ago (Worden & Boettcher, 1990). Early childhood education has seen tremendous change in the past two decades as a result of national and state initiates. Thus, updating information regarding acquisition of uppercase letter writing is important for understanding the development of writing skills. More importantly however, an issue that has not received adequate attention to date is the question of whether there is a discernible sequence in children’s acquisition of letter writing skills, especially uppercase manuscript letters. Information regarding the order in which children learn to write letters has relevance for the assessment and instruction of letter writing. Information about uppercase letter-writing skills is important, because we have no guidelines for how best to introduce letters for teaching writing; Schlagal (2007, p. 197) noted that “How the alphabet is best introduced is not a settled matter nor is the order in which letters are best taught”. One way to address this issue is by examining which letters are learned before others.

The purpose of this study was to examine the dimensionality and reliability of letter writing with the aim of determining whether a developmental sequence existed in how children learn to write the letters of the alphabet. We examined dimensionality via a series of parametric and non-parametric factor analytic methods, and reliability (including the relative difficulty and precision of writing individual letters) using Item Response Theory (IRT) analysis. Given prior research about differences in the acquisition of knowledge about letter names and letter sounds (e.g., Justice et al., 2006; McBride-Chang, 1999; Phillips et al., 2012; Piasta, Petscher, & Justice, 2012; Treiman & Kessler, 2003) and writing of lowercase letters with grade school (Graham et al., 2001; Lewis & Lewis, 1964, Newland, 1932; Pressey & Pressey, 1927) and uppercase letters with preschool (Worden & Boettcher, 1990) children, we expected to find a hierarchy of difficulty for letter writing. However, we did not have a specific hypothesis regarding a sequence because of lack of prior research.

In addition to examining the sequence of how children learn to write the uppercase letters of the alphabet, we also examined whether there were gender differences in the development of letter-writing skills. Results of previous research, focused on qualitative differences in letter-writing skills between genders, have not been clear cut. Some research with older children indicates qualitative differences in letter-writing skills between boys and girls in favor of girls when features such as the height of letters, connections between letters, and neatness of writing are considered (e.g., Blote & Hamstra-Bletz, 1991; Massey, 1983; Ziviani & Elkins, 1984). In contrast, some research indicates no differences in the quality of letter-writing skills between the two groups (e.g., Graham et al., 2001; Hill, Gladden, Porter, & Cooper, 1982; Lamme & Ayris, 1983). For instance, Hill et al. asked 2nd and 3rd grade students to copy 10 lowercase manuscript letters and scored these letters for legibility which included letter size, completeness of strokes in the letter, formation of the dots (for the letter j, for example), closing of the circles (for letters such as q, and a). Their results indicated no difference in the qualitative aspects of letter writing between boys and girls. Another line of research examining automaticity of letter writing in grade school children consistently indicates differences between boys and girls. Work by Berninger et al. (e.g., Berninger & Fuller, 1992; Berninger, Nielsen, Abbott, Wijsman, & Raskind, 2008) has shown that girls perform better than boys on measures of alphabet fluency (i.e., the ability to write lowercase letters of the alphabet in a timed task). Gender differences have not been examined when children begin to learn about letter writing. We do not know the answers to questions such as: do girls write more letters than boys during the early stages of learning to write? Or are some letters more difficult than others for boys versus girls? If gender differences are found, this information may have important practical implications. For example, teachers may be able to use this information to provide greater support and instruction to a particular group when teaching them how to write letters.

METHOD

Participants

Participants for this study were 471 preschool children. Data for these children were collected as part of two larger studies examining the emergent writing skills of preschool children. Participants for Sample 1 were recruited from a mid-size city in western

Pennsylvania, and participants for Sample 2 were recruited from a mid-size city in western Pennsylvania and a mid-size city in north-central Florida. Children for Sample 1 were recruited from 11 preschools and private pre-K centers. These centers were selected to represent children from a wide range of SES backgrounds; four schools were categorized as mid to low SES (50–75% students receive subsidies) and seven schools were categorized as high to mid SES (25–49% students receive subsidies). One child was home-schooled. Likewise, children for Sample 2 were recruited from 54 public and private pre-K centers. Of these, 23 schools were categorized as mid to low SES, 29 schools were categorized as high to mid SES, and two schools were categorized as high SES (less than 25% of students receive subsidies). Parental consent was obtained for each participating child. The children were primarily English-speaking and had no known developmental disorders as ascertained from teacher report. Across both samples, there were 155 three-year olds, 161 four-year olds, and 155 five-year olds. Demographic information about the participants in each of the two samples is provided in Table 1.

Procedures

Data on various literacy measures were collected as part of two larger studies by trained research assistants who tested the children individually at their child-care centers or preschools. These assessments were conducted in a quiet room and completed in two to three sessions that lasted approximately 20 to 40 min each depending on each child’s ability to attend and stay on task. Only the data on letter writing are reported in this study.

Letter-writing measure

To assess letter-writing skills, children were asked to write each of 26 letters of the alphabet. The examiner said a letter in a fixed random order, and the children were asked to write the letter. The examiner introduced the task by saying, “I want you to write some letters for me. If you do not know them all, that is all right. Just try your best.” The examiner then pointed to where the child needed to begin writing and continued with the directions, “We are going to write some uppercase or capital letters. Write a capital D”. On items 1 and 2 only, if the child wrote a lowercase letter, the examiner said, “That’s a lowercase letter. I want you to write a capital D.” Children’s responses were scored dichotomously as correct or incorrect. To account for age and developmental level, children were not penalized for poor penmanship or letter reversals. Children were also not penalized for writing lowercase letters because we were mainly interested in finding out if children knew how to write a letter. As expected for this age group, children wrote uppercase letters. Of the total number of letters written, only 6.2% of the letters in Sample 1 and 5.8% of the letters in Sample 2 were scored as being written as lowercase. The letters that were generally scored as written in lowercase were the letters i, m, x, and t. In case of all four letters, it was difficult to determine if the child was writing in lowercase or if the handwriting was simply small. In the case of the letter i, for example, children often write an uppercase i with a vertical line and without the lower and upper horizontal lines. They write a lowercase i in the same manner (often omitting the dot over the *i* and printing it smaller), such that a meaningful distinction between lowercase and uppercase versions could not be made with certainty. The same was true for the letters m and x. Internal consistency reliability for the letter-writing task was high (Cronbach’s α=.98).

Inter-rater reliability

Inter-rater agreement for the letter writing measure was established through a three-step process. First, directed by the first author, a scoring rubric with examples was created. Second, two research assistants were trained to use the rubric with a small subset of children. Once they reached 100% agreement, each research assistant individually scored the writing samples. Third, inter-rater reliability was calculated for each of the 26 letters as the percent agreement between the two raters. Scoring reliability varied with each letter and ranged from 87% for the letter T to 98% for the letter Y. The average inter-rater reliability across all 26 letters was 92%. All scoring discrepancies were resolved through discussion, and the final score entered was the one agreed upon by both raters.

Data analysis

Dimensionality of letter writing—The dimensionality of letter-writing scores was examined by applying a combination of methods to assess the structure of responses to the letter-writing task. Scores obtained on each of the 26 letters of the alphabet comprised the observed item responses, which provided an index of children’s latent letter writing ability. One of the first steps was to verify one of most important assumptions in IRT, namely unidimensionality, which states that a score from a test can only have meaning if the items measure one dimension. In other words, we wanted to verify that the 26 letters of the alphabet yielded a single factor that presumably reflects children’s letter-writing knowledge. This assumption is often connected to a stringent set of criteria, leading Stout (1990) to argue for “essential unidimensionality” testing. Conceptually, Stout argued that a test is unidimensional if, for a given level of ability, the average covariance over pairs of items on the test is small in magnitude, as opposed to zero.

Several options exist to test the extent of unidimensionality including parametric and nonparametric methods in either an exploratory or a confirmatory approach to assess test structure (Tate, 2003). To assess comprehensively the structure of letter-writing scores, a combination of methods were used including: (a) a parametric exploratory analysis using Mplus (Muthén & Muthén, 2008), (b) a parametric confirmatory analysis using Mplus, (c) a nonparametric exploratory analysis using Stout’s DIMTEST software, and (d) a nonparametric confirmatory analysis using DETECT program and index (Zhang & Stout, 1999).

In the parametric exploratory factor analysis, the ratio of eigenvalues, comparative fit index (CFI, Bentler, 1990), Tucker–Lewis index (TLI; Bentler & Bonnett, 1980), root mean square error of approximation (RMSEA, Browne & Cudeck, 1992), and standardized root mean residual (SRMR) were used to evaluate model fit. CFI and TLI values greater than or equal to 0.95 are considered to be minimally sufficient criteria for acceptable model fit, and RMSEA and SRMR estimates of b0.05 are desirable. With the exception of the ratio of eigenvalues, these indices were also used to evaluate the parametric confirmatory factor analysis model.

The principle of essential unidimensionality, evaluated through the nonparametric exploratory analysis using DIMTEST is that if unidimensionality is demonstrated, then the assumption of local independence will also hold. A non-significant T value from DIMTEST indicates that the factor structure is essentially unidimensional. In the nonparametric confirmatory model, a DETECT index less than 0.1 provides evidence of an essentially unidimensional model.

Reliability of letter writing

Following the assessment of the dimensionality of scores, a multiplegroup item response theory (IRT) analysis using Mplus software (Muthén & Muthén, 2008) was used to examine inter-letter patterns in how letter writing develops. Two parameters were examined across the different ages of students: (a) Item difficulty – to quantify the degree to which one letter was easier (or more difficult) to write than another letter, and (b) Item discrimination – to indicate the extent to which individual letters distinguish latent ability levels among respondents. Item response theory maintains several advantages over classical test theory in that (a) the estimates of item difficulty and discrimination are unbiased, even with unrepresentative samples, (b) the item statistics and ability scores are reported on the same scale, and (c) the relative precision of scores (or reliability) can vary across the range of ability scores but is not sample dependent (Embretson & Reise, 2000). Because students in the sample were of various ages, an advantage of multiple-group IRT is that the item parameters may be equated across age and hence be utilized to examine performance across different ages (i.e., ages 3–5 years in this study). Several types of IRT models are available for estimating the IRT parameters, such as the one-parameter (1PL) and two-parameter (2PL) logistic models. To evaluate the improved efficiency in model selection, the difference in the log likelihood between the 1PL and 2PL models was first calculated and then divided by the log likelihood of the 1PL (Haberman, 1978). This method of fit guards against making model decisions solely based on statistical significance and provides an estimate akin to a variance reduction estimate in multilevel modeling.

Using an IRT framework to estimate internal consistency is further advantageous, because reliability in an IRT framework differs from conventional estimations of internal consistency, as it is typically described as a relationship between the individual ability of the student and the amount of error variance surrounding the person specific estimate. Although this evaluation of reliability may be different, the error variance around the student’s score may be converted into a marginal average coefficient of reliability that may be interpreted similar to a Cronbach’s alpha estimate of internal consistency (Samejima, 1977).

Once a 1PL or 2PL model was selected, item invariance across gender groups was tested to estimate the extent to which writing letters significantly differed between boys and girls when controlling for the ability of the individual (i.e., differential item functioning [DIF]). Formal testing of DIF was conducted with a multiple indicator multiple cause (MIMIC) analysis in Mplus (Muthén & Muthén, 2008); moreover, a series of four standardized and expected score effect size measures were generated using VisualDF software (Meade, 2010) to quantify various technical aspects of score differentiation between the gender groups. First, the signed item difference in the sample (SIDS) index was created, which describes the average unstandardized difference in expected scores between the groups. The second effect size calculated was the unsigned item difference in the sample (UIDS). This index can be utilized as supplementary to the SIDS. When the absolute value of the SIDS and UIDS values are equivalent, the differential functioning between groups is equivalent; however, when the absolute value of the UIDS is larger than SIDS, it provides evidence that the item characteristic curves for expected score differences cross, indicating that differences in the expected scores between groups change across the level of the latent ability score.

The D-max index is reported as the maximum SIDS value in the sample, and may be interpreted as the greatest difference for any individual in the sample in the expected response. Lastly, an expected score standardized difference (ESSD) was generated, and was computed similar to a Cohen's (1988) d statistic. As such, it is interpreted as a measure of standard deviation difference between the groups for the expected score response with values of .2 regarded as small, .5 as medium, and .8 as large.

RESULTS

Descriptive statistics, reported as the average percent correct, for the letter-writing measure by age are reported in Table 2. Children showed a full range of letter writing knowledge. Differences between the age groups was significant, $F(2, 468)=139.61$, $p<.001$. The 4-year-old children outperformed the 3-year-old children ($p<.001$), and the 5-year-old children outperformed the 3- and 4-year-old children ($p<.001$).

The mean percent correct across all letters for 3-year-old children was 11%, compared with 40% for 4-year-old children, and 74% for 5-year-old children. The range of proportions for 3-year-old children was 1% for the letter K to 42% for the letter O. Comparatively, the most difficult letter to write for 4-year-old children was G (27% correct) and the easiest was O (73% correct). The letters Z and J were equally the most difficult (59% correct) and O was the easiest letter (95% correct) for 5-year-old children. The biggest shift in the proportion correct between the 3- and 5-year-old children was for the letter X, where an 87% difference was observed between the two groups. Conversely, the smallest shift of 51% occurred between the age groups for the letter U.

Dimensionality

The parametric exploratory factor analysis was initially specified to estimate one-factor and two-factor models to compare any differences between a unidimensional and multidimensional structure. Results from the one-factor solution provided strong evidence for a unidimensional model: $\chi^2(299)=330.15$, $p=.10$; CFI=0.99, TLI=0.99; RMSEA=.02; SRMR=.02. Moreover, the ratio between the first and second eigenvalues was large at 46.69 (i.e., 21.90/0.47). A summary of the factor structure matrix for the unidimensional model is provided in Table 3. The loadings between the letters and the factor ranged from 0.86 for the letter M to 0.95 for the letter P. The two-factor model yielded a nearly identical fit to the one-factor solution: $\chi^2(274)=296.31$, $p=.17$; CFI=0.99, TLI=0.99; RMSEA=.01; SRMR=.02. The chi-square difference test resulted in a non-significant difference between the two models ($\Delta\chi^2=34$, $\Delta df=25$, $p=.87$), further suggesting that the data from the parametric exploratory model were unidimensional. Parametric confirmatory testing produced similar results as the previous analysis. With a one-factor model, the fit indices were: $\chi^2(299)=330.15$, $p=.10$; CFI=0.99, TLI=0.99; RMSEA=.02.

Stout’s nonparametric, exploratory analysis yielded an identical conclusion, with a non-significant T score estimated (T=1.34, p= .091), indicating that the null hypothesis of unidimensionality could not be rejected. Finally, a DETECT value of 0.015 was estimated for the nonparametric, confirmatory analysis, indicating that the underlying data structure was essentially unidimensional.

Item analysis and reliability

The convergence of multiple dimensionality tests on an essentially unidimensional structure led us to fit the item response models to the entire set of scores using both the 1PL and 2PL models. The log likelihood difference between the two favored the 2PL model (ΔG^2=45, Δdf=24, p<.01), with a 10% improvement in efficiency gained by utilizing the 2PL model indicating that letters reliably differed on both discrimination and difficulty parameters. Discrimination (i.e., a parameter) and difficulty (i.e., b parameter) estimates from the multiple-group IRT analysis are reported in Table 3. Across all items, the mean item difficulty was .24. Difficulty values in IRT typically range from −3 to 3, and may be interpreted as z-scores, with lower values representing easier items, higher values representing harder items, and estimates close to zero indicating average difficulty. A value of 0.24 would suggest that items trended toward being slightly hard. The range of difficulties was −.62 for the letter O to 0.55 for the letter J, reflecting that letters varied in difficulty. Of the 26 letters, only two were estimated as being easy items (i.e., O and L). The mean discrimination was 2.59, and individual discrimination parameters ranged from 1.74 for the letter O to 3.21 for the letter F. Discrimination scores greater than 1.0 are viewed as desirable for the a parameter. The resulting standard errors from the ability scores in the 2PL model were used to calculate the precision of ability scores across the continuum of ability.

Similar to item difficulties, student ability in IRT typically ranges from −3 to 3, with lower values indicating lower ability and higher values indicative of higher ability. A summary of the information and standard error curves for student ability on the letter-writing task are presented in Fig. 1. The solid, horizontal reference line in the figure corresponds to a standard error associated with a classical test theory reliability of 0.80, while the dashed reference line corresponds to a reliability of 0.90. What is most noticeable in this figure is that students with an ability score from approximately −1.2 to approximately 1.80 would have a reliable estimate of their ability at a level of at least .80. In terms of a normal distribution, it would be expected that 82% of individuals would fall between a score of −1.2 to 1.5; thus, this proportion would reflect the percentage of individuals who would obtain a precise score of at least α=.80 when taking the letter-writing task. Moreover, students with an ability score between −.80 and 1.60 would have a precise estimate at level of α=.90. Students with an ability score outside of these ranges would have less reliable estimates of their ability; however, this constitutes a small portion of the sample.

Differential item functioning

Prior to conducting a DIF analysis to examine differences in gender, some descriptive statistics were conducted. The mean letter writing score for girls was 18.32 (SD=17.63; range 0–52) and for boys was 13.38 (SD=5.47; range 0–49); the difference between the two groups was statistically significant F (1, 469)=10.34, p<.001. These gender-related differences were not a result of age differences as boys and girls in the sample did not differ in age, F (1, 469)=.95, *p*=.58.

Results from the item-invariance testing and effect size estimation are reported in Table 4. DIF testing indicated that statistically significant differences between boys and girls in the difficulty of items existed only for the letters B (*p*=.034) and X (*p*=<.001). However, the relationship between the overall test ability and gender was such that girls had an average ability score higher than boys (γ=1.03, *p*<.001). Although, significant DIF effects were noted only for the letters B and X, effect size indices (i.e., SIDS, D-Max, and ESSD) generally support the statistical findings in that differences were observed between genders. In fact, the mean of the ESSD was *d*= −0.17 with a range of *d*= −0.08 to −0.26, indicating that, on average, a very small practical difference was estimated between boys and girls in their expected score when controlling for ability, with girls having a consistently higher likelihood of correctly writing the letter.

DISCUSSION

The primary goal of this study was to examine the dimensionality of letter writing and to explore the developmental sequence of letter writing knowledge in children aged 3 to 5 years because of the importance of letter writing to early writing development (e.g., Graham & Harris, 2000; Puranik et al., 2011). Preschool children were asked to write from memory the uppercase letters of the manuscript alphabet. This study provides empirical data regarding the letters children first learn to write. It replicates and extends findings from previous research indicating that there are significant inter-letter differences in how children acquire letter writing knowledge of each of the 26 letters of the English alphabet and contributes to the sparse research base on the letter-writing skills of preschool children. We are unaware of any study to date that has examined empirically the dimensionality and reliability of letter writing with the aim of ascertaining the best sequence for introducing letters of the alphabet using an IRT analysis. Notably, the findings from this study have important implications for the assessment and instruction of letter writing.

Similar to research on the development of letter-name and letter-sound knowledge, the IRT analyses demonstrated that writing letters varied in terms of their relative difficulty and discrimination. This finding is consistent with research on writing of lowercase letters with grade school children (e.g., Graham et al., 2001; Lewis & Lewis, 1964, Newland, 1932; Pressey & Pressey, 1927). The findings of this study demonstrated that, generally, a hierarchical scale existed among letters in the letter-writing task, and that only one scale was extracted providing strong evidence regarding letter writing as a unidimensional construct.

The mean percent correct across all letters was 11% for 3-year-old children, 40% for the 4-year-old children and 74% for the 5-year-old children. The average performance of preschoolers in this study is slightly higher than those previously reported. The average percent correct across all letters as reported by Worden and Boettcher (1990) was 23% and 53% for 4- and 5-year-old children, respectively. Pre-K programs are under increasing national, state, and local pressure to produce better child results. Increasing demands regarding school readiness have led to increased initiatives since 1990. These initiatives, which have translated into an increased emphasis by preschool programs on promoting emergent literacy skills and alphabet knowledge in young children, could have contributed to an increase in performance from Worden and Boettcher.

The 10 easiest letters for preschool children to write were: O, L, A, B, X, T, H, I, E, and P, whereas the 10 hardest letters to write were: J, K, Z, G, Q, V, U, Y, R, and N. Our findings are generally consistent with Worden and Boettcher's (1990) findings. Seven out of 10 of the easiest uppercase letters for the 4-year-olds in their study were also easy for 4-year-olds in this study (O, L, A, T, H, I, and E), and seven out of 10 of the easiest uppercase letters (O, A, X, B, C, P, and T) from their study were also easy for the 5-year-olds in this study. Seven out of 10 of the most difficult uppercase letters in Worden and Boettcher's study were also difficult for the 4-year-olds in this study (J, V, G, K, N, Y, and Z), and eight out of 10 of the most difficult uppercase letters from their study (R, Y, G, V, Q, U, J, and Z) were also most difficult for the 5-year-olds in this study. Our finding also corroborate the findings of Stennett et al. (1972) who reported that the letters O, E, H, and I were the easiest to write and the letters D, Z, G, and N were the most difficult to write for children from kindergarten to grade 3 and Ritchey's (2008) findings who reported that the letters A, O, X, L were the easiest and the letters D, G, J, Y, and Z were the most difficult for kindergarten children to write. There was also a large overlap between the easiest and most difficult lowercase letters for children to write as reported by previous studies (e.g., Graham et al., 2001; Lewis & Lewis, 1964) and our findings regarding the easiest and most difficult uppercase letters for children to write.

Taken together, the findings from this and previous studies suggest the existence of an approximate developmental sequence to how children learn to write letters. However, our IRT analyses indicate that this sequence is more perceptible at the two ends (easiest and difficult) of the continuum of children's letter writing skills. In accordance with previous findings, there are some letters that are more easily acquired and some alphabet letters that were difficult for young children learning to write. In contrast, there was less evidence for a clear sequence for letters in the middle. Letter writing for some letters such as C, D, F, S, and W appear to be more idiosyncratic as evidenced by difficulty parameters from this study and lack of overlap between the percent correct frequencies from this and previous studies.

Jones and Mewhort (2004) attempted to estimate the uppercase letter frequency in English using a large corpus of approximately 183 million words. Five of the 10 letters that children in this study found easiest to write (A, B, T, I, and P) were among the 10 most frequently occurring uppercase letters on Jones and Mewhort's list. These findings are in line with Pollo et al.'s (2009) results that the letters used by preschool children in their early spelling was influenced by the letters' textual frequency. However, there were also five letters that were among the easiest for children to write (O, L, X, H, and E) but are not among the most frequently occurring uppercase letters in English. For example, the letter X ranks among the least frequently (25 out of 26) occurring uppercase letters in print; yet, it was one of the easiest letters to write. A frequently played game is Tic–Tac–Toe and may explain why children are proficient with writing the letters X and O. Why would the letters L, H, and E be among the easiest for preschoolers to write? Factors besides frequency, such as the simplicity of the letters shapes and ease of writing the letter may be other contributors to the development of letter-writing skills. Of the letters that children found hardest to write, eight of the 10 (exceptions were R and N) were among the 10 least frequently occurring uppercase letters. In addition to being letters that occur relatively infrequently, several of these letters are also the most complicated and perhaps most difficult to write for children (e.g., J, G, Q, and R). Thus, letter frequency and difficulty or ease of writing a letter contributes to letter-writing acquisition.

Recently, Phillips et al. (2012) reported on an IRT study of preschool children's letter-name knowledge. Of the 10 letters that children found easiest to name, eight were also among the easiest for children to write (O, B, A, X, P, E, T, and H). Furthermore, eight of the 10 most difficult letters for preschool children to name were also among the most difficult for children to write (V, U, Q, N, J, G, Z, and Y). This large overlap between children's letter-name and letter-writing knowledge should not come as a complete surprise as past studies have reported strong relationships (r's=.80–.83) between letter naming and letter writing in young children (Molfese, Beswick, Molnar, & Jacobi-Vessels, 2006; Worden & Boettcher, 1990). Studies examining children's letter knowledge have found that children with higher letter-naming skills generally have higher scores on letter writing. Perhaps knowing letter names may facilitate letter writing or letter writing could boost children's knowledge of letter names or the relationship may be bidirectional. Diamond, Gerde, and Powell (2008) examined growth in Head Start children's name writing and letter knowledge at three time points and found that children whose name writing was more sophisticated (i.e. contained more letters) knew more letter names. They reported bidirectional influences of writing on growth of letter names, and of letter names on growth of writing competence. A discussion concerning influences, although important, is beyond the scope of this study. Although there is large overlap between the letter-name and letter-writing skills, the relationship is not a hundred percent. Two of the most difficult letters to name (I and L; Phillips et al., 2012) were among the easiest for children to write. Whereas some factors contributing to letter naming and letter writing might be the same, there may also be differences. Identifying these factors jointly might be useful direction for future research.

Prior research on gender differences in letter-writing skills has focused mainly on qualitative aspects of letter writing and has yielded inconclusive results. Whereas, quality of letter writing was not examined in this study, our findings indicate that the overall letter writing score for girls was higher than for boys. When examining differences in difficulty with specific letters, however, the results were less conclusive. DIF testing indicated no significant differences between boys and girls in the difficulty of items, except when writing the letters B and X. When controlling for the ability of the children, we should expect that there is no relationship between the gender of the child and their likelihood of writing the letter correctly. For instance, there should be no difference in the probability of correct letter writing for girls and boys with an ability score of 0 (average) because they are at the same level of ability. Although significant differences between genders was noted for only two letters, examination of the effect sizes between the groups, indicate that there were small but perhaps practical differences between boys and girls; given the same ability level, girls showed a higher probability of writing a letter correctly than did boys. Whereas this finding might suggest that our measure of letter writing may have some bias, examination of the effect sizes suggests that the bias is small. Motor development differences between boys and girls might be a better explanation for these observed gender differences. Additionally, previous research with older children in early elementary grades indicates that girls are better at retrieval of letters from orthographic memory for writing (Berninger & Fuller, 1992) and may also explain some of these gender differences. These small differences between genders might suggest differential instruction for boys and girls.

Implications for practice

Our finding regarding a discernible sequence in the development of letter-writing skills could be used to make some suggestions for the assessment and instruction of letter writing with preschool children. Given that letter differences (difficulty and discrimination) were noted, both educators and researchers could consider these differences when assessing letter writing. If the goal is to assess school readiness, the letter-writing tasks could include letters with high discrimination but low difficulty (e.g., L, I, T, X, and E); however, to distinguish the more precocious students, letters with high discrimination and high difficulty (e.g., G, K, R, U, V, and Y) may be more appropriate. In the current educational environment that emphasizes progress monitoring, our findings could perhaps aid in the development of alternate forms to monitor children’s development of letter-writing skills There appear to be letters with some degree of redundancy in difficulty, discrimination, or both (for e.g., N and W, I and T). Such letters can be used to create alternate forms of assessment for the purposes of progress monitoring and tracking children’s development of letter-writing skills.

Our results using more sophisticated statistical techniques than used previously corroborate previous research and indicate that some letters are easier and more readily acquired than others. However, most current literacy-focused preschool curricula introduce letters in an ABC order (see Justice et al., 2006). Informal conversations with teachers and observations of the preschool classrooms in which this research was conducted further confirm these findings. Yet, the results of this study indicate that the ABC order is not the order in which children develop letter-writing skills. It may be that the sequence of letter acquisition identified in this study is also a good instructional sequence. Alternatively, it may be the case that teachers should introduce the most difficult letters and that the easier letters will be learned implicitly or more easily. An argument could also be made for the introduction of easy letters such that it might provide children the motivation to learn the more difficult letters; the focus of teaching should be on those letters that children have the greatest likelihood of learning. Finally, the similarity of our results to those of Phillips et al. (2012) suggests a potential benefit for introducing the same letters for teaching letter names and for letter writing. Prior to making instructional decisions regarding the order in which letters should be introduced, however, several questions must be answered. At the very least, the findings from this study should give us reason to pause and reconsider the sequence in which letters are introduced. These questions regarding the sequence of letter-writing instruction are worthy avenues for future research.

Although preliminary, our results regarding letter differences could also mean differential instruction. Perhaps when teaching difficult letters, teachers must be aware that some letters might need extra attention and review during instruction. Teachers may need to allocate more time to teach these difficult letters (e.g., Q, J) compared to the letters acquired more easily (e.g., X, O). Furthermore, differences in letter writing performance between genders and results of the DIF analysis also suggest that differential instruction for teaching letter writing may be warranted; boys may require more time and attention than girls.

Limitations and future direction

We used a sophisticated statistical method to examine the reliability and dimensionality of letter writing with the aim of ascertaining a sequence to how children learn to write letters. Our results indicate that letter frequency and difficulty or ease of writing a letter contribute to the sequence in which children learn to write letters. In this study, we focused our analyses on inter-letter differences, and did not consider differences between children. One such difference between children could include whether the letter is the first letter of a child's name or letters in a child's name (other than the first letter). Previous research indicates that the first letter children learn to write is the first letter of their name (e.g., Bloodgood, 1999; Both-de Vries & Bus, 2008, 2010; Diamond et al., 2008; Levin & Ehri, 2009; Levin, Both-de Vries, Aram, & Bus, 2005; Puranik et al., 2011; Puranik & Lonigan, 2012; Welsch, Sullivan, & Justice, 2003). However, Phillips et al. (2012) reported that accounting for the first name of the child in their IRT analyses of letter names did not change their results substantially, i.e., the general pattern of development of letter names stayed the same. Yet, the results might be different for children's letter writing. Other factors contributing to the development of letter writing could include letter type. Similar to research on letter type (e.g., vowel–consonant letters such as M, L, and S versus consonant–vowel letters such as B, T, and G) influencing the learning of letter names, letter types could influence learning how to write letters. The influence of the first letter in a child's name, letters in a child's name, and letter type on letter-writing skills has not been examined before and could be a good extension of this research.

Given the age of the participants and because our goal was to determine a sequence of development of letter-writing skills, we were generous in our scoring and did not specifically examine legibility of letters. Although letters do not have to be written perfectly to be considered legible, past research indicates that the legibility of individual letters predicts overall text legibility in older children (Graham et al., 2001). More fine-grained analysis that includes factors that contribute to legibility (e.g., correct proportion, correct formation, reversals) similar to the work of Graham et al. (2001) would also be a worthy extension of this research. Finally, whereas we were able to examine letter-writing skills in a large and diverse group of preschool children, we did not systematically observe classroom instruction. Performance in letter writing could also be affected by program type and provide some answers regarding why some letters are learned before others. One area in need of further exploration would be examining the impact of classroom instruction on the development of letter-writing skills.

According to most state standards, children in preschool are expected to print some letters and write symbols, words, or simple phrases that communicate an idea or use letter-like shapes, symbols, and letters to convey meaning and write their names. In the current environment of school readiness, it is extremely important for preschool children to begin kindergarten being developmentally ready to participate actively in the classroom curriculum. The findings of this study and subsequent questions raised could lead to guidelines that preschool teachers could follow regarding the order in which letters should be taught.

Acknowledgments

Support for carrying out this research was provided in part by grant R305A090622 from the Institute of Education Sciences, US Department of Education.

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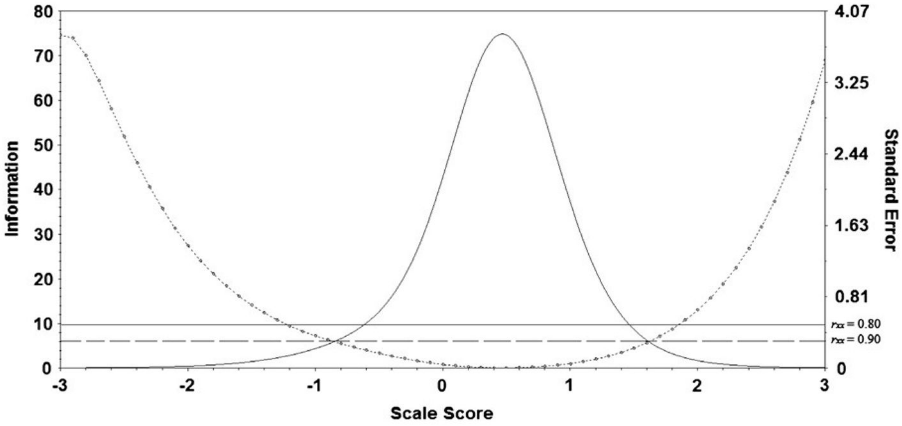

Fig. 1.

Test information (solid curve) and standard error (dashed curve) plot for letter writing ability scores.

Table 1

Demographic characteristics of children in the two samples.

Sample characteristics	Sample 1	Sample 2
N	104	367
Mean age (SD)	4 years; 3 months (8.5)	4 years; 5 months (8.9)
Age range (years; months)	3 years; 7 months to 5 years; 11 months	3 years; 0 months to 5 years; 10 months)
Time of testing	Oct-Dec	Mar-May
Number of preschools/ daycare centers	12	54
Gender		
Male	49 (47.1%)	172 (46.9%)
Female	55 (52.9%)	195 (53.1%)
Ethnicity		
White	64 (61.9%)	228 (62.1%)
Black	33 (31.4%)	103 (28.1%)
Hispanic	2 (1.9%)	8 (2.2%)
Asian	5 (4.8%)	14 (3.8%)
Other	-	14 (3.8%)

Table 2

Mean performance on the letter-writing task by age.

Letter	3-year-olds		4-year-olds		5-year-olds	
	Mean	***SD***	**Mean**	***SD***	**Mean**	***SD***
A	14%	34%	51%	50%	84%	37%
B	12%	33%	52%	50%	84%	37%
C	10%	30%	36%	48%	83%	38%
D	14%	35%	34%	48%	77%	42%
E	12%	32%	43%	50%	78%	41%
F	9%	28%	40%	49%	71%	46%
G	6%	24%	27%	44%	64%	48%
H	13%	34%	49%	50%	76%	43%
I	12%	32%	43%	50%	82%	39%
J	5%	23%	28%	45%	59%	49%
K	1%	12%	29%	46%	61%	49%
L	24%	43%	59%	49%	83%	37%
M	12%	32%	45%	50%	75%	43%
N	8%	27%	34%	47%	70%	46%
O	42%	50%	73%	45%	95%	21%
P	10%	29%	41%	49%	80%	40%
Q	7%	26%	31%	46%	61%	49%
R	5%	21%	35%	48%	70%	46%
S	7%	26%	35%	48%	74%	44%
T	14%	35%	43%	50%	80%	40%
U	10%	30%	33%	47%	61%	49%
V	7%	25%	31%	46%	63%	48%
W	7%	26%	35%	48%	71%	45%
X	5%	23%	49%	50%	92%	28%
Y	7%	25%	35%	48%	67%	47%
Z	6%	24%	32%	47%	59%	49%

Table 3

Dimensionality of letter writing and IRT results.

Letter	Parametric explanatory factor analysis			IRT 2PL	
	1-factor	2-factor		Vertical equating	
	Loading	f1-loading	f2-loading	Discrimination	Difficulty
A	0.95	0.95	−0.12	2.836	0.026
B	0.89	0.88	−0.08	1.932	0.038
C	0.94	0.94	0.08	2.708	0.206
D	0.91	0.91	−0.15	2.245	0.225
E	0.94	0.94	−0.08	2.823	0.174
F	0.95	0.95	−0.10	3.205	0.292
G	0.92	0.92	0.02	2.753	0.486
H	0.89	0.89	0.12	2.088	0.143
I	0.95	0.95	−0.01	2.873	0.135
J	0.88	0.88	0.02	2.046	0.547
K	0.92	0.92	0.01	2.732	0.539
L	0.92	0.92	0.09	2.342	−0.127
M	0.86	0.86	0.05	1.814	0.196
N	0.91	0.91	−0.06	2.457	0.358
O	0.87	0.87	0.12	1.744	−0.624
P	0.95	0.95	−0.05	3.180	0.190
Q	0.89	0.89	0.08	2.207	0.477
R	0.94	0.94	−0.03	3.068	0.374
S	0.93	0.93	−0.14	2.835	0.311
T	0.94	0.95	0.08	2.888	0.122
U	0.91	0.91	0.13	2.307	0.427
V	0.92	0.92	0.12	2.598	0.455
W	0.91	0.91	0.09	2.406	0.338
X	0.93	0.93	−0.12	2.374	0.056
Y	0.93	0.93	0.24	2.798	0.382
Z	0.89	0.89	−0.05	2.141	0.500

Table 4

Item-level invariance test and effect size statistics.

Letter	Differential item testing			Effect size statistics			
	γ	SE	*p*-value	SIDS	UIDS	D-Max	ESSD
A	.131	.118	.265	−0.08	0.08	−0.24	−0.20
B	.279	.132	.034	−0.07	0.09	−0.20	−0.20
C	.226	.120	.059	−0.05	0.05	−0.17	−0.14
D	.053	.121	.660	−0.05	0.06	−0.15	−0.14
E	.067.	.115	.556	−0.10	0.10	−0.31	−0.26
F	−.006	.108	.952	−0.07	0.07	−0.23	−0.18
G	.071	.123	.562	−0.08	0.09	−0.26	−0.21
H	.073	.116	.525	−0.09	0.09	−0.19	−0.24
I	.135	.116	.245	−0.09	0.09	−0.29	−0.23
J	.079	.116	.496	−0.03	0.05	−0.12	−0.09
K	.237	.126	.060	−0.06	0.06	−0.18	−0.15
L	−.084	.114	.461	−0.11	0.11	−0.26	−0.27
M	.149	.117	.203	−0.07	0.07	−0.14	−0.21
N	.090	.111	.419	−0.04	0.07	−0.18	−0.10
O	.114	.146	.435	−0.06	0.06	−0.13	−0.20
P	.159	.122	.190	−0.06	0.06	−0.23	−0.16
Q	−.006	.117	.959	−0.06	0.07	−0.18	−0.18
R	.157	.125	.209	−0.09	0.09	−0.29	−0.22
S	.153	.109	.160	−0.05	0.05	−0.17	−0.13
T	.038	.116	.744	−0.07	0.07	−0.20	−0.17
U	−.134	.113	.236	−0.06	0.06	−0.16	−0.18
V	.020	.115	.861	−0.03	0.03	−0.09	−0.08
W	.140	.113	.214	−0.07	0.07	−0.19	−0.19
X	.648	.135	<.001	−0.02	0.02	−0.07	−0.06
Y	.049	.119	.679	−0.08	0.08	−0.23	−0.21
Z	-	-	-	−0.08	0.09	−0.23	−0.23
Test	1.031	.125	<.001				

Note. γ = DIF coefficient; SIDS = signed item difference in sample; UIDS = unsigned item difference in sample; D-Max =maximum difference in sample; ESSD =expected score standardized difference.

The letter Z was not tested due to model fit indices suggesting it was not warranted.