Article

Item Response Analysis of Uppercase and Lowercase Letter Name Knowledge

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Abstract

Letter name knowledge in the preschool ages is a strong predictor of later reading ability, but little is known about the psychometric characteristics of uppercase and lowercase letters considered together. Data from 1,113 preschoolers from diverse backgrounds on both uppercase and lowercase letter name knowledge were analyzed using Item Response Theory. Results indicated that uppercase and lowercase form a single dimension. Uppercase letters tended to be easier and more discriminating but had a narrow range of difficulty. Visual confusability (e.g., b vs. d) was an important aspect of both discrimination and difficulty. Including lowercase letters in the assessment of letter name knowledge increases its range to enable effective measurement of children with higher ability. A practical implication is that assessments of letter name knowledge can have fewer items and measure an extended range of ability while maintaining high levels of reliability.

Keywords

letter knowledge, measurement, preschool, reading

Letter name knowledge (LNK) is among the best predictors of children's early literacy skills (Scarborough, 1998; Whitehurst & Lonigan, 1998) and later reading ability, including decoding and comprehension in elementary school (Denton, West, & Walston, 2003; National Early Literacy Panel, 2008; Whitehurst & Lonigan, 2001) and continuing through high school (Cunningham & Stanovich, 1997). Furthermore, the relationship between LNK and reading ability appears to be causal in nature (Foulin, 2005). Reading ability, in turn, is predictive of many important lifespan outcomes, including educational attainment, career trajectory, and income (Kirsch, Jungeblut, Jenkins, & Kolstad, 1993). Thus LNK is a crucial skill that can have impacts far beyond the early childhood period in which it is learned.

A few studies have considered the psychometric characteristics of the latent trait of LNK, with most focusing on uppercase letters (Bowles, Skibbe, & Justice, 2011; Justice, Pence, Bowles, &

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Wiggins, 2006; Phillips, Piasta, Anthony, Lonigan, & Francis, 2012) and much fewer on lowercase (Drouin, Horner, & Sondergeld, 2012; Pence Turnbull, Bowles, Skibbe, Justice, & Wiggins, 2010). A key finding is that uppercase letters tend to span a narrow range of child abilities. Although neither study explicitly reports the range, both Phillips et al. (2012) and Drouin et al. (2012) found that uppercase letters span only about 1.25 SD of the underlying LNK construct, indicating that uppercase LNK is a highly constrained skill (Paris, 2005). This restriction of range limits the utility of uppercase LNK. As lowercase letters are learned later than uppercase letters (Mason, 1980; Smythe, Stennett, Hardy, & Wilson, 1971; Worden & Boettcher, 1990), children who are at or near ceiling on an assessment of uppercase LNK may not have such a ceiling effect on lowercase LNK, so including lowercase letters in the measurement of LNK may improve the measurement of LNK and therefore increase the strength of LNK's association with reading, particularly among more advanced emergent readers and beginning readers.

Including lowercase letters is appropriate only if uppercase and lowercase letters measure the same LNK construct. Only one study has considered uppercase and lowercase LNK together (Drouin et al., 2012), concluding that LNK is a single construct encompassing both uppercase and lowercase LNK. However, Drouin et al. (2012) employed a Rasch fit approach, which has validity issues for detecting dimensionality (Smith, 1996; Tennant & Pallant, 2006), and other research has concluded that a Rasch approach to psychometric analysis of uppercase LNK is not appropriate because of lack of fit to the Rasch model (Bowles et al., 2011). Thus it remains unclear if uppercase letter knowledge and lowercase letter knowledge form the same latent trait. If not, uppercase LNK and lowercase LNK may be differentially important in the development of literacy skills and offer a new avenue for research into the role of letter name knowledge in the development of reading. On the other hand, if uppercase and lowercase LNK do form the same latent trait, measurement of combined uppercase-lowercase LNK may offer an opportunity to extend the range of measurement of LNK.

The lack of psychometric research creates challenges for most effectively measuring LNK and for understanding its role in the development of reading. The need for psychometric examination of LNK is particularly acute for lowercase letters, which are more common in print and are included in many assessments of LNK, including in large-scale studies (e.g., Administration for Children and Families, 2006). The goal of this study is therefore to examine the psychometric characteristics of uppercase and lowercase letters within a single measurement framework, including dimensionality and patterns of item discrimination and difficulty. In particular, we address the following research questions:

Research Question 1: Do uppercase and lowercase form the same latent trait? In other words, is LNK unidimensional or bidimensional with separate uppercase and lowercase latent traits?

Research Question 2: What is the pattern of difficulty and discrimination for uppercase and lowercase letters? Based on previous findings (Mason, 1980; Smythe et al., 1971; Worden & Boettcher, 1990), we expect that uppercase letters will be, in general, easier than lowercase letters, that is, children will in general be more likely to know an uppercase letter than a lower letter. We have no expectations regarding patterns of discriminations.

Research Question 3: How is the measurement of a child's LNK impacted by including both uppercase and lowercase letters?

We consider these research questions with two samples of preschool children, a primarily low-SES urban sample and a primarily middle-SES suburban sample (see below for a detailed description of the samples). In addition, the samples used different formats for assessing LNK: in one case a series of flash cards and in the other a sheet of randomly ordered letters from the Phonological Awareness Literacy Screening for Preschool (Invernizzi, Sullivan, Meier, & Swank,

Table 1. Participant Demographic Information.

Variable	Low-SES urban sample	Middle-SES suburban sample
Age in months		
- Mean	51	49
- *SD*	4.6	7.1
Gender		
- Female	49%	49%
- Male	51%	51%
Race/ethnicity		
- White/Non-Hispanic	42%	80%
- African American	37%	3%
- Other	17%	13%
Mother education		
- <HS	19%	1%
- HS	22%	6%
- HS+T	15%	5%
- SC	28%	18%
- AA	9%	8%
- BA	6%	29%
- >BA	1%	32%
English as primary language	97%	92%
Area		
- Urban	81%	0%
- Suburban	5%	100%
- Rural	14%	0%

Note. < HS = less than high school, HS = high school diploma, HS+T = High school diploma plus some technical training, SC = some college, AA = two year degree, BA = Bachelor's degree, and >BA = higher than a bachelor's degree.

2004). Previously research has been inconclusive on whether the format of assessment affects the psychometric properties of uppercase LNK (Bowles et al., 2011; Phillips et al., 2012). Considering the above research questions in two samples allows for stronger conclusions through cross-validation. Therefore, we have the supplemental research question:

Supplemental Research Question 1: Do the sample characteristics and the format of assessment (sheets vs. flash cards) affect the measurement of lowercase and uppercase LNK?

Method

We used letter name responses from archival data from two separate studies of preschool-age children to examine and cross-validate the psychometric properties of lowercase and uppercase LNK. Demographic information for both samples is provided in Table 1. The first, primarily low-SES urban, sample consisted of 551 children in the Sit Together And Read project (STAR; Justice, Kaderavek, Fan, Sofka, & Hunt, 2009). Children in the study were given two subtests of the *Phonological Awareness Screening for Preschool* (PALS-PreK; Invernizzi, Sullivan, Meier, & Swank, 2004): Upper Case Alphabet Recognition and Lower Case Alphabet Recognition. For each subtest, children were presented with a single sheet containing the 26 individual letters randomly ordered in four columns. Letters were presented in Zaner-Bloser font (e.g., HIJ). Children were asked to name each letter one by one. On average, children were able to identify 8.69 uppercase letters (*SD* = 9.19) and 6.66 lowercase letters (*SD* = 8.06).

The second, primarily middle-SES suburban sample of 562 children were from the Michigan Longitudinal Study of Early Literacy Development (MLSELD). To assess LNK, children were asked to respond to the prompt "What is the name of this letter?" when shown a letter printed in 150-point font on a flashcard. Letters were presented one at a time. All 26 uppercase letters were presented first in Times New Roman font, followed immediately by all 26 lowercase letters presented in Verdana font (e.g., HIJ; Verdana has a more standard g shape: g). Eight forms with different randomized letter orders were used, with form assigned randomly to each child. On average, children were able to identify 12.21 uppercase letters (SD = 8.17) and 8.84 lowercase letters (SD = 8.17).

Results

Dimensionality

To examine dimensionality, we ran exploratory and confirmatory item factor analyses (Wirth & Edwards, 2007) in Mplus using the WLSMV estimator (Muthén & Muthén, 1998-2010) for both samples as well as the combined sample. In the confirmatory analyses, we allowed residual correlation between each uppercase letter and its lowercase counterpart, as previous research has found that, even controlling for overall levels of LNK, children are more likely to know a lowercase letter if they also know the corresponding uppercase letter (Pence Turnbull et al., 2010). For the low-SES sample, the exploratory analysis supported a single factor with a very large eigenvalue (41.00; second eigenvalue = 1.00). The single factor model had adequate to excellent fit (CFI = .995; TLI = .995; RMSEA = .067). Addition of a second factor did not appreciably improve fit (CFI = .997; TLI = .996; RMSEA = .056). A GEOMIN rotation of the 2-factor solution did not yield a differentiation between uppercase and lowercase; all letters loaded strongly on the first factor (smallest loading = .74 for lowercase b), while the second factor had no large loadings (largest loading = .42 for uppercase X). The confirmatory factor analysis yielded identical conclusions. The 1-factor solution fit very well (χ^2 = 198, df = 171, p = .08; CFI = .998; TLI = 1.000; RMSEA = .017). The 2-factor solution showed a significant but small improvement in fit over the 1-factor solution ($\Delta\chi^2$ = 4.9; Δdf = 1; p = .03) but did not appreciably improve absolute fit (CFI = .999; TLI = 1.000; RMSEA = .016). The correlation between the factors was nearly 1 (r = .989). Conclusions from the middle-SES sample and the combined samples yielded similar results and are not described in detail. Overall, the results clearly supported a single LNK dimension.

Invariance Across Format

We next examined the supplemental research question: whether there are differences between the two samples in the way the single LNK latent trait is measured by the 52 letters. We adapted a typical approach to examining measurement invariance across two samples for dichotomous outcomes using Mplus (Muthén & Muthén, 1998-2010). Constraining loadings and thresholds to be equal introduced a statistically significant amount of misfit ($\Delta\chi^2$ = 108; Δdf = 41; $p < .01$) but the constrained model still fit very well (CFI = .996; TLI = .999; RMSEA = .035) and there was only a small effect on the absolute fit statistics (ΔCFI = .002; ΔTLI= 0.001; ΔRMSEA = .015). Constraining the residual correlations between corresponding uppercase and lowercase letters to be equal in both samples did not introduce significant misfit ($\Delta\chi^2$ = 14.6; Δdf = 11; p = .20). Thus we conclude that there is no difference between the two samples in the way LNK is measured with uppercase and lowercase letters. After establishing measurement invariance across the samples, it is clear that there are substantial differences in LNK between the individuals in the two samples; individuals in the middle-SES sample had higher mean LNK (Cohen's d = .34, $p < .01$).

Table 2. Difficulty and Discrimination of Uppercase and Lowercase Letters.

	Uppercase		Lowercase	
Letter	Difficulty	Discrimination	Difficulty	Discrimination
A/a	–0.062	3.169	0.987	2.227
B/b	–0.243	2.637	1.303	1.561
C/c	0.185	2.780	0.185	3.164
D/d	0.303	3.010	1.531	1.875
E/e	0.253	3.470	0.509	2.866
F/f	0.408	3.619	0.808	3.227
G/g	0.459	3.375	1.275	2.845
H/h	0.321	3.115	1.081	2.380
I/i	0.495	3.005	0.476	3.363
J/j	0.437	2.398	0.923	2.138
K/k	0.217	2.650	0.272	3.086
L/l	0.388	3.182	1.475	1.741
M/m	0.199	2.547	0.537	2.713
N/n	0.461	3.686	0.993	2.944
O/o	–0.392	3.268	–0.333	4.188
P/p	0.280	3.927	0.589	2.537
Q/q	0.484	3.418	2.044	1.948
R/r	0.146	3.797	0.644	3.002
S/s	0.120	2.946	0.223	3.367
T/t	0.341	2.742	1.125	2.083
U/u	0.571	3.402	0.855	3.145
V/v	0.758	3.181	0.813	3.527
W/w	0.341	2.607	0.388	2.768
X/x	–0.083	2.480	0.037	2.591
Y/y	0.418	3.065	0.533	3.348
Z/z	0.389	3.144	0.468	3.222

Pattern of Discrimination and Difficulty

We next examined the pattern of difficulty and discrimination using a standard IRT analysis program, Bilog-MG (Zimowski, Muraki, Mislevy, & Bock, 2003), using the standard identification constraint of fixing the latent level of LNK (i.e., ability or theta in typical IRT terminology) to have mean 0 with a standard deviation of 1. Results for each letter are presented in Table 2 and graphed in Figure 1. Discriminations varied substantially: for uppercase letters, discriminations ranged from 2.40 (J) to 3.93 (P), while for lowercase letters, they ranged from 1.56 (b) to 4.12 (o). Uppercase letters on average (3.10) were more discriminating than lowercase letters (2.76; $t_{50} = 2.27$, $p = .03$). Five lowercase letters are highly confusable because of visual similarities: b and d are mirror images of each other, as are p and q, and the letter l is visually similar to the number 1. These letters tended to have much lower discriminations than the other letters, including the four lowest discriminations among all 52 letters (in order from lowest: b, l, d, and q; p is the 11th least discriminating), indicating that these visually confusable letters are less effective indicators of overall LNK than other letters. There was little relationship for discriminations between an uppercase letter and its lowercase counterpart ($r = .22$, $p = .28$).

For uppercase letters, difficulties ranged from –0.39 (O) to 0.76 (V), a range that is only slightly larger than the unit standard deviation of ability, suggesting that uppercase letters measure only a narrow range of LNK. For lowercase letters, difficulties ranged from –0.33 (o) to 2.04

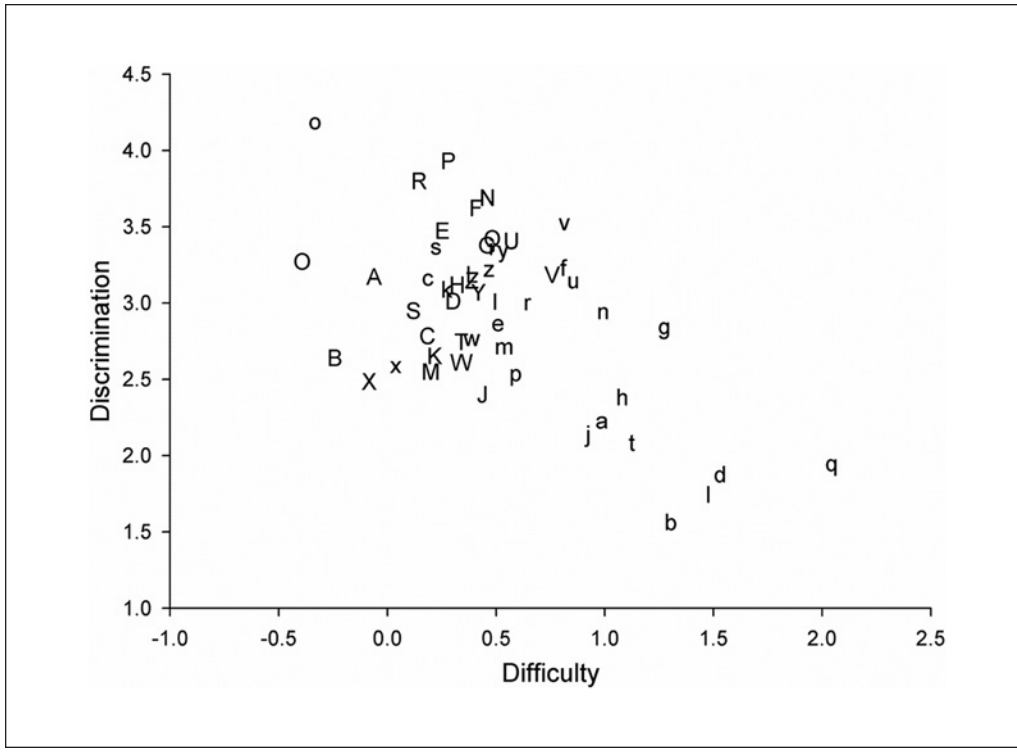

Figure 1. Difficulty and discrimination of uppercase and lowercase letters.

(q), a much greater range than uppercase letters with a considerably higher upper bound. As expected, lowercase letters were substantially more difficult on average than uppercase letters (0.76 vs. 0.28; $t_{50} = 4.25$, $p < .01$). The five visually confusable lowercase letters tended to have higher difficulties; the 4 most difficult letters were visually confusable (from highest: q, d, l, b; p is the 16th most difficult letter among both lowercase and uppercase letters). There was a moderate relation between uppercase and lowercase difficulty ($r = .40$, $p = .04$).

Measurement of a Child's LNK

The final analyses addressed how assessing both uppercase and lowercase letters affects the measurement of LNK relative to assessing uppercase only. Because 48 of the 52 letters had discriminations above 2, (only 4 visually confusable lowercase letters were not), reliability is very high. When assessed with only uppercase letters, the reliability as estimated within Bilog-MG was .91 and increased only slightly to .94 when lowercase letters were included (reliability for lowercase only was .88). Thus, including both uppercase and lowercase letters for measuring LNK has only a small effect on overall precision of measurement. However, uppercase letters had a very limited range of difficulty, while lowercase letters encompassed a much broader range particularly in the more difficult direction. Thus measurement of higher levels of LNK is improved with inclusion of lowercase letters. As shown in Figure 2, the *SE* of measurement is reduced substantially for higher levels of LNK. For example, within our samples, 98 children (9% of those with complete uppercase data) knew all 26 uppercase letters. The average *SE* of measurement for these children was reduced from .51 to .23, a 54% reduction (more properly, a 79% reduction in error variance).

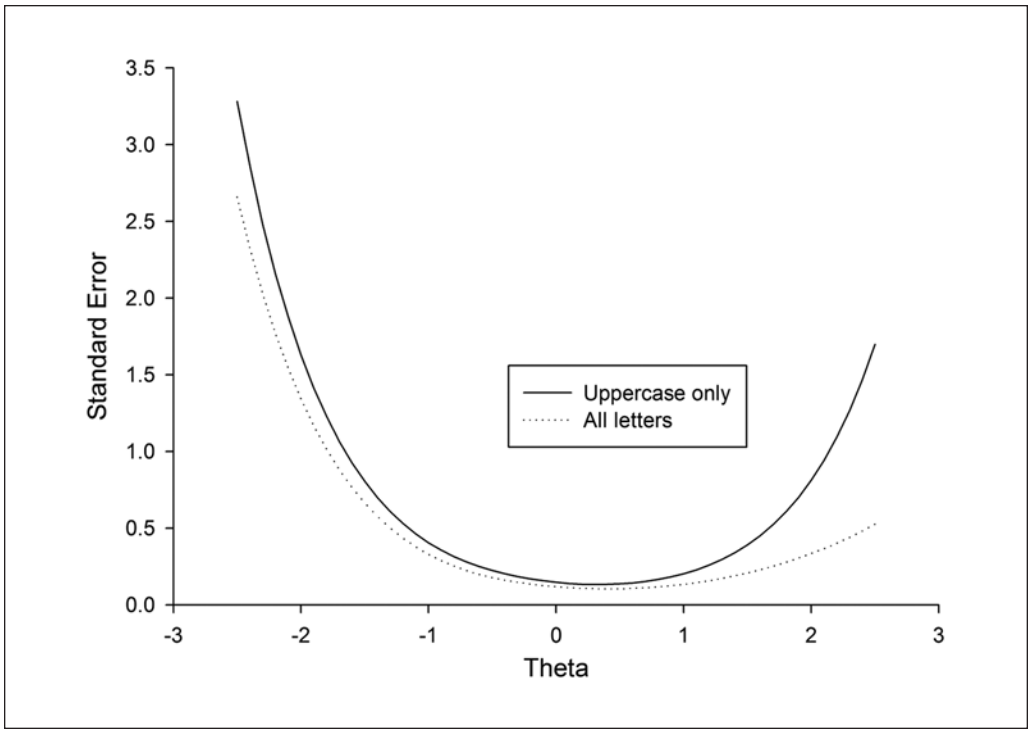

Figure 2. Standard error of measurement for uppercase and all letters.

Discussion

The present study sought to investigate the psychometric characteristics of uppercase and lowercase LNK. The results of our work point to four major findings regarding our research questions about the psychometric characteristics of uppercase and lowercase LNK: (RQ 1) uppercase and lowercase LNK form a single latent trait; (RQ 2) lowercase letters are substantially more difficult on average than uppercase letters, whereas uppercase letters on average are more discriminating than lowercase letters; (RQ 3) the measurement of LNK, particularly for children with higher LNK, may be improved by including lowercase letters in assessments; and (S1) the measurement of LNK is not impacted by the sample characteristics or format of assessment (sheets vs. flash cards). In the following section, we elaborate on each of the findings and explore ways in which specific findings extend current understandings of the measurement of LNK.

Unidimensionality of LNK

Findings from our analyses clearly supported a single LNK dimension, as these findings were substantiated in analyses with both samples separately as well as the combined sample. This finding establishes that LNK is a single entity encompassing both uppercase and lowercase letters. Although previous studies have examined the psychometric properties of uppercase letters and lowercase letters separately, this study highlights that uppercase LNK and lowercase LNK are manifestations of the same underlying LNK and should be considered together in both research and practice. We note, however, that the conclusion of unidimensionality applies only to letter naming and may not apply to other aspects of letter knowledge, such as letter writing (e.g., Treiman & Kessler, 2004).

Pattern of Difficulty and Discrimination

Although uppercase and lowercase letters form a single dimension, there are clear differences between the two types of letters. In terms of letter difficulty, study results confirmed our hypothesis that lowercase letters are more difficult on average than uppercase letters. (e.g., Mason, 1980; Smythe et al., 1971; Worden & Boettcher, 1990). Children may first learn uppercase letters and then generalize the knowledge to lowercase letters, a developmental pathway supported by other studies examining the likelihood of a child knowing individual lowercase letters (Pence Turnbull et al., 2010; Treiman & Kessler, 2004). Alternatively, typical practice in the classroom and home may impact children's acquisition of knowledge of uppercase letters before lowercase letters. There is little support for the hypothesis that there are formal efforts at the school or curricular level to encourage preschool teachers to teach uppercase before lowercase (Piasta & Wagner, 2010), and the various curricula used by the teachers in our study either did not explicitly endorse this method of teaching letters or did not specify how to teach uppercase and lowercase letters. Furthermore, little is known about how parents support the development of LNK except some indications that parents emphasize the letters in a child's own name (e.g., Hood, Conlon, & Andrews, 2008).

A third potential explanation highlighted by this study is that visual characteristics of lowercase letters make them more difficult to learn. We found that some of the difficulty difference between uppercase and lowercase was accounted for by five visually confusable lowercase letters, which tended to have higher difficulties (q, d, l, b, p). It may be that other attributes of lowercase letters, such as size or complexity of visual patterns, may also contribute to their higher difficulty. Previous studies examining lowercase letters have indicated that similar visual characteristics in the shape of letters can lead to children's challenges in discrimination and recall of letter names (e.g., b and d; p and q) (Goikoetxea, 2006; Smythe et al., 1971; Treiman, Kessler, & Pollo, 2006). Thus our study substantiates these prior findings and suggests that visual characteristics of the letters, particularly visual confusability, should receive further attention in studies of lowercase letters.

Turning to discrimination, results from the present study indicate that there was substantial variability in discrimination, with uppercase letters on average more discriminating than lowercase letters. The variability in discriminations, along with the nonuniform distribution of difficulty, highlight that the simple total number of letters named correctly is not an optimal method for estimating a child's underlying LNK. For example, for a child with an average level of LNK ($\theta = 0$), an increase of .1 in the underlying LNK is associated with an expected increase of 5 letters, whereas for a child 1 *SD* above the mean ($\theta = 1$), an increase of the same amount is associated with a much lower increase in expected score of only 2 letters. Our use of IRT to understand LNK accounts for the lack of interval scaling with the total score. We therefore recommend that assessments of LNK should use IRT scaling to maximize the validity of findings.

Measurement of a Child's LNK

Results from the present study also revealed that lowercase letters are more effective than uppercase letters when measuring children with high levels of LNK. Within our sample, 9% of children knew all 26 uppercase letters, but only about .6% also knew all 26 lowercase letters. Thus, including lowercase letters in the measurement of LNK may improve the measurement of LNK, particularly for more advanced emergent readers. This study also highlights that assessing both uppercase and lowercase letters in their entirety may not be necessary, as the reliability associated with all 52 letters far exceeded levels typically considered acceptable. Instead, assessments of LNK may only require the inclusion of a selection of uppercase and lowercase letters, which would reduce the time and cost associated with assessing children's LNK. That is,

assessments of LNK can both be extended in range by including lowercase letters and shortened in length while maintaining high reliability by an appropriate selection of letters. Letters with similar difficulty as other letters but with lower discrimination (e.g., J relative to N) may be eliminated from the assessment with little loss of information. For example, by selecting the most discriminating items across a range of difficulties (A, P, R, U, g, o, q, v), an assessment consisting of only these 8 letters would have an IRT-based reliability of .82. This dramatic reduction in the number of items while maintaining high reliability is particularly important in light of the challenges of testing young children, such as maintaining focus, and the need to limit testing time in both educational and research settings. As another possibility, alternative forms can be created that can be administered quickly and potentially used to help identify children who are making appropriate progress in learning LNK and aid in identifying children who are struggling with early literacy skills.

Invariance Across Samples

Finally, we found no differences between the samples in the *way* LNK is measured, although the *level* of LNK differed substantially, even though the samples differed in both demographics (low-SES urban and middle-SES suburban) and format of assessment (sheets of randomly ordered letters and flash cards). This allows for stronger conclusions through cross-validation and helps resolve contradictory findings in previous research (Bowles et al., 2011; Phillips et al., 2012). We note a minor limitation with this conclusion that format was not randomly assigned, so that although there are no differences between the formats at the letter level, there is a possibility that letters as a whole are easier for one format than another. Such a possibility is impossible to disentangle from differences between the two samples of children in mean LNK. An experimental approach with random assignment to format is necessary to consider this possibility.

The finding of invariance is noteworthy because the samples were both large and divergent, differing in SES, urban status, format of assessment, and even font. A finding of invariance is particularly strong because there were so many potential sources of measurement differences; if there were differences between the samples, they were quite likely to be uncovered. This strong support for invariance suggests that less dramatic differences between samples are unlikely to affect the validity of research conclusions. As a particular example, it is unlikely that the font used to assess LNK will affect measurement. Previous research varies substantially in the choice of format (e.g., sheets and flash cards in this study) and font (e.g., Times New Roman, Verdana, and Zaner-Bloser used in this study), and many studies neglect to report such potentially important methodological choices. Despite such differences (when reported), this study reassuringly highlights that the results from previous research are directly comparable with each other.

Conclusion

Findings from this study contribute to the growing body of research exploring the nature of alphabet learning in young children, particularly in regard to psychometric characteristics of uppercase and lowercase LNK. Investigation into the development and measurement of LNK is a particularly relevant avenue for research, given that LNK has been established as one of the best predictors of early literacy skills. The present study indicates that a single construct encompasses both uppercase and lowercase LNK. In addition, as established in previous research, results show that lowercase letters are more difficult on average than uppercase letters. Furthermore, study findings suggest that the measurement of LNK may be improved by including lowercase letters in assessments. The results of this work have important implications on the measurement of LNK.

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