Theoretical Explanations for Preschoolers' Lowercase Alphabet Knowledge

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Purpose: Letter knowledge is a key aspect of children's language development, yet relatively little research has aimed to understand the nature of lowercase letter knowledge. We considered 4 hypotheses about children's lowercase letter knowledge simultaneously—uppercase familiarity, uppercase-lowercase similarity, own-name advantage, and frequency in printed English—as well as 3 interactions.
Method: Participants were 461 children ranging in age from 3 to 5 years, all of whom attended public preschool programs serving primarily children from low-income homes, who completed a letter naming task.
Results: Uppercase familiarity was the strongest predictor of children's lowercase alphabet knowledge; children were more than 16 times more likely to know a lowercase letter if they knew the corresponding uppercase letter. Uppercase-lowercase similarity and frequency in printed English also predicted children's lowercase letter knowledge, as did the interaction between uppercase familiarity and own-name advantage and the interaction between uppercase familiarity and uppercase-lowercase similarity.
Conclusions: Findings suggest that transference from uppercase letter knowledge may be a primary mechanism for lowercase letter knowledge and that young children's knowledge of the lowercase alphabet letters is multiply determined.

KEY WORDS: alphabet, preschool, letter knowledge

Young children's language development includes acquiring knowledge about oral and written language systems (Nation & Snowling, 2004). Although the developmental fields have a long history of generating and testing theories that increase understanding of how and when children acquire specific oral language skills (Roth, Speece, & Cooper, 2002), theoretical understanding of children's development of written language skills is much less refined (e.g., Whitehurst & Lonigan, 1998). Nonetheless, increased understanding of how young children acquire specific skills regarding written language has salient implications not only for advancing basic developmental theories but also for improving clinical and educational practices focused on remediating children's early difficulties with written language acquisition given relations between early written language skills and later reading achievement (for a recent meta-analysis, see National Early Literacy Panel, 2009). In the present study, we tested specific theories regarding young children's development of one particular aspect of written language skill—namely, knowledge of the lowercase alphabet letters.

Alphabet knowledge is one of the strongest unique predictors of children's later reading skills and is consequently of great interest to

developmental and educational researchers (Adams, 1990; Chiappe, Siegel, & Gottardo, 2002; Foulin, 2005; Scanlon & Vellutino, 1996; Schatschneider, Fletcher, Francis, Carlson, & Foorman, 2004; Storch & Whitehurst, 2002). The relation between alphabet knowledge and later reading skills is based on the premise that children who can readily associate phonemes (smallest units of spoken language) with graphemes (smallest units of written language that represent phonemes and combinations of phonemes) use this knowledge in service of decoding unfamiliar words (Coyne & Harn, 2006; Torgesen, 2002). Prior to acquiring knowledge of this alphabetic principle, research has demonstrated that knowledge of letter names facilitates children's ability to link print to speech. This point was demonstrated in work by Treiman and Rodriguez (1999), which showed that pre-reading children who were taught plausible print-pronunciation pairs (e.g., TM = team, TM = tame) learned significantly more pairs when the name of the letter was present in the word (e.g., /ti/ in team but not in tame). These findings point to the important role that children's knowledge of letter names—that is, their alphabet knowledge—plays in word decoding, even before children have a complete understanding of conventional phoneme–grapheme correspondences.

Much of the research on children's development of alphabet knowledge has focused on children's recognition and naming abilities for uppercase alphabet letters (e.g., Justice & Ezell, 2001; Justice, Pence, Bowles, & Wiggins, 2006; McBride-Chang, 1999; Treiman & Broderick, 1998; Treiman, Tincoff, & Richmond-Welty, 1997), although some studies have examined children's learning of lowercase letters (e.g., McCormick & Mason, 1981; Smythe, Stennett, Hardy, & Wilson, 1971; Treiman, Cohen, Mulqueeny, Kessler, & Schechtman, 2007; Treiman & Kessler, 2004; Worden & Boettcher, 1990). Although lowercase letters make up the majority of the print we read, young children demonstrate a preference for names written in uppercase (Treiman, Cohen, et al., 2007), and they tend to gain proficiency with uppercase letters before lowercase letters (Mason, 1980; Smythe et al., 1971; Worden & Boettcher, 1990). That uppercase alphabet knowledge, in general, outpaces lowercase alphabet knowledge is of particular interest considering that lowercase letters appear more frequently than uppercase letters in conventional printed media.

The present study addresses children's knowledge of the individual lowercase alphabet letters by predicting the probability that a child knows a specific lowercase letter from several specific hypotheses examined simultaneously. More generally, the present study contributes to research that simultaneously investigates predictors of important precursors to children's later reading skills, such as socioeconomic status and age as predictors of phonological awareness (McDowell, Lonigan, & Goldstein, 2007). It is important to note that although the specific hypotheses tested in the present study are not necessarily new (i.e., many replicate prior work), the present study is the first of which we are aware to test the hypotheses simultaneously.

Theories Guiding Lowercase Alphabet Knowledge

Presently, relatively little is known regarding the extent to which certain child characteristics and specific letter features relate to children's knowledge of lowercase letters. To contribute to this literature, this study examined the lowercase alphabet knowledge of children ranging in age from 3 to 5 years and tested four hypotheses concerning the probability that they would know specific lowercase letters. This study is guided in part by theories of word learning, as these can provide guidance on potential mechanisms supporting the acquisition of lowercase alphabet letters. Like other words, letters are units of language, consisting of one or more spoken sounds. Unlike conventional words, however, individual letters are not principal carriers of meaning, and children do not receive exposure to letter names in the same way that they receive exposure to the names for objects and actions in their environment. Even so, it is plausible that children might learn individual letters (uppercase and lowercase) in a similar fashion to other early-learned lexical items by initially forming associations between spoken letter names and the individual printed letters they represent. As informed by these theories and by information gleaned from previous research examining children's letter name knowledge, the present study was able to test specific hypotheses suggesting that children will be more likely to know those lowercase letters that (a) correspond to uppercase letters with which they are familiar, which we refer to as the *uppercase familiarity hypothesis*; (b) most closely resemble their uppercase counterparts, which we refer to as the *uppercase-lowercase similarity hypothesis*; (c) occur first in a child's own name, referred to as the *own-name advantage hypothesis*; and (d) occur most frequently in printed English, referred to as the *frequency in printed English hypothesis*. We describe each of these hypotheses in turn.

Uppercase familiarity hypothesis. Children tend to gain proficiency with uppercase letters before lowercase letters (e.g., Worden & Boettcher, 1990); thus, the uppercase familiarity hypothesis posits that children should be more likely to know the lowercase alphabet letters for which they know the uppercase counterparts than the lowercase letters for which they do not know the uppercase counterparts. If alphabet letters operate similarly to other lexical items, children should be likely to extend their understanding of known uppercase letters to their lowercase counterparts using the principal of lexical

extension, which posits that words label objects, actions, and attributes other than the original referent (e.g., Golinkoff, Mervis, & Hirsh-Pasek, 1994). However, it is also possible that knowledge of an uppercase letter could make lowercase letter learning more difficult, considering that children may be less likely to accept a homophone as the name of a new object than a novel label (e.g., Backscheider, Gelman, Martinez, & Kowieski, 1999; Merriman, Marazita, & Jarvis, 1995). It is not clear, however, whether children's tendency to avoid accepting homophones as the name of a new object applies to children's learning of alphabet letters. If the anti-homophone bias holds for alphabet letters, children might experience difficulty in learning the name of lowercase letters for which they already know the uppercase counterpart. Thus, it is a distinct possibility that knowing an uppercase letter may negatively relate to children's lowercase alphabet knowledge. However, if children are on the cusp of being able to override an anti-homophone bias, or if they are able to suspend the assumption altogether, they should be willing to accept more than one referent (i.e., one uppercase letter and one lowercase letter) for each letter name, in which case there would be a positive relation between children's uppercase and lowercase alphabet knowledge.

Uppercase-lowercase similarity hypothesis. The uppercase-lowercase similarity hypothesis posits that children should be more likely to know those lowercase letters that visually approximate their uppercase letter counterparts than those lowercase letters that are more visually different from their uppercase counterparts (Treiman & Kessler, 2004). In addition to previous research examining children's letter name knowledge, this hypothesis is also supported by research concerning the role of object shape in supporting children's lexical extensions. Several empirical studies have indicated that shape, as opposed to other attributes, is an important basis for object word extension during the preschool years (Baldwin, 1989; Landau, Smith, & Jones, 1998; Smith, Jones, & Landau, 1992). Evidence from studies of adults suggests that the perceptual features of letters (i.e., letter shape) might contribute to the difficulty or ease that children experience in learning visibly similar letters. For example, similarity judgments about pairs of uppercase and lowercase letters can be made independent of the phonetic information that letters carry (i.e., on the basis of visual perception alone; Boles & Eveland, 1983).

In the present work, we utilized research from Boles and Clifford (1989), who had undergraduate students rate the similarity of uppercase and lowercase letters using both pure-case pairs (e.g., GQ, gq) and mixed-case pairs (e.g., Gq, gQ). Specifically, the researchers constructed a matrix of 2,704 (52 × 52) letter pairs (e.g., Gq, gQ, GQ, gq) and then randomly divided the matrix of pairs into eight subsets of 338 pairs each. Each of 32 undergraduate student participants rated three randomly selected subsets (i.e., 1,014 pairs), which were presented to them in a random order. Each of the eight subsets was rated by 12 participants. Of relevance to the present study are the visual similarity values of uppercase and lowercase pairs with the order of presentation for uppercase and lowercase letters collapsed (e.g., combined ratings for Aa and aA). (See the Appendix for the visual similarity values used in the present study.) Cluster analyses conducted by Boles and Clifford revealed that participants' visual similarity ratings were based on such features as acute angles (e.g., Z, z), curvature (e.g., C, c, O, o), vertical bisection and symmetricality about a horizontal axis (e.g., K, k, X, x), diagonal features (U, u, V, v, W, w, Y, y), and a strong vertical component (e.g., I, i, J, j, T, t). The visual similarity values and cluster analyses presented by Boles and Clifford allowed us to test the probability that children know specific lowercase letters according to the uppercase-lowercase similarity hypothesis.

Own-name advantage hypothesis. The own-name advantage hypothesis states that children should be more likely to know the lowercase letter corresponding to the initial letter in their first name than other letters. Empirical support for this hypothesis is strong, particularly with respect to uppercase letters. Justice et al. (2006) found that preschool-age children are more than 11 times more likely to know the first letter of their own name than an uppercase letter not in their own name, whereas they are only slightly more likely to know the name of an uppercase letter present in their own first name other than the first letter. Although the own-name advantage does not extend to letters in children's last names (Treiman & Broderick, 1998), the advantage for letters in one's first name has been found to operate for children across a variety of alphabetic scripts and cultural communities (Hoorens & Todorova, 1988; Nuttin, 1985, 1987; Treiman, Kessler, & Pollo, 2006; Treiman, Levin, & Kessler, 2007). Presumably, children receive more exposure to the initial letter of their first names than to other letters, and they feel an inherent sense of ownership over this letter, rendering this letter more salient than other letters (Nuttin, 1985, 1987). Research on the early lexical development of young children confirms that children learn the names for salient objects (Hirsh-Pasek, Golinkoff, & Hollich, 2000; Hollich, Hirsh-Pasek, & Golinkoff, 2000) and actions (Brandone, Pence, Golinkoff, & Hirsh-Pasek, 2007) more easily than for nonsalient objects and actions, and it appears that this trend extends to alphabet letters as well.

Although empirical support for the own-name advantage hypothesis is strong for uppercase letters, less is known about how this might relate to children's knowledge of lowercase letters. Treiman and Kessler (2004) found that kindergarten-age children demonstrated a reliable advantage for knowing the first letter of their

first name when it was presented in uppercase or lowercase. Because the own-name advantage has received less attention with respect to lowercase letter knowledge, replication of Treiman and Kessler's finding would provide stronger support for the hypothesis. As tested in the present study, if the own-name advantage hypothesis holds for lowercase letters, children should be more likely to know the lowercase letter corresponding to the initial letter of their first name than other letters.

Frequency in printed English hypothesis. The frequency in printed English hypothesis states that children should be more likely to know those letters that appear more frequently in printed English than those letters that appear less frequently. Frequency appears to be an important factor in word learning generally (Hoff & Naigles, 2002; Naigles & Hoff-Ginsberg, 1998; Rice, Oetting, Marquis, Bode, & Pae, 1994; Wang & Koda, 2005), although it remains unclear how frequency relates to letter knowledge. Jones and Mewhort (2004) calculated uppercase and lowercase letter frequency using several large-scale English corpora, and they found that relative frequencies for uppercase and lowercase letters in printed text are not equivalent (see the Appendix). Specifically, the correlation between uppercase and lowercase letter counts was determined to be .63, which is smaller than the correlation established by Tinker (1928) of .93.

Research about the effect of frequency of printed letters on children's alphabet knowledge has provided mixed results. Smythe et al. (1971) found an effect of frequency on children's knowledge of uppercase letters, although no such effect was detected for children's knowledge of lowercase letters. More recent research has revealed a frequency effect for Israeli children learning Hebrew (a unicase alphabet), but it did not find similar effects in English (only uppercase letters were examined; Treiman, Levin, & Kessler, 2007). In the present study, we sought to examine this effect using a larger sample and corpus of frequency data for lowercase letters. Specifically, Smythe et al. used a small corpus (the first 500 words of a preprimer text used in the study school), which may not have been representative of the print that children encounter in everyday settings. In the present study, we incorporated frequency ratings derived from a larger corpus (approximately 183 million words; see Jones & Mewhort, 2004), providing a potentially more valid test of the association of frequency of occurrence of letters in English to children's alphabet knowledge. If the frequency in printed English hypothesis holds, children in the present study should be more likely to know lowercase letters that occur more frequently in printed English than lowercase letters that occur less frequently.

Research Aims

This study was designed to inform our understanding of how children acquire knowledge about a specific symbolic system, which they must master to become full participants in their society (DeLoache, 2004); in this case, children's knowledge of lowercase letters, including their understanding of the link between the written symbols and the letters they represent, is a prerequisite to becoming proficient readers of the English language (Bialystok, 1991; Bialystok & Martin, 2003). The present study used a cross-sectional design to examine the independent contributions of four hypotheses concerning children's lowercase letter learning. We tested the likelihood that children would know lowercase letters that (a) correspond to uppercase letters with which they are familiar (uppercase familiarity hypothesis), (b) most closely resemble their uppercase counterparts (uppercase-lowercase similarity hypothesis), (c) occur first in their own names (own-name advantage hypothesis), and (d) occur most frequently in printed English (frequency in printed English hypothesis). In addition, considering prior evidence demonstrating that young English-speaking children learn uppercase letters prior to lowercase letters, we explore whether uppercase familiarity interacts with the other three theories tested in the present study (i.e., uppercase-lowercase similarity, the own-name advantage, and frequency in printed English) to promote children's lowercase letter knowledge.

Method

Participants

Participants were 461 children attending preschool programs in a mid-Atlantic state. The preschool programs attended by these children specifically targeted children who were deemed to be "at risk" on the basis of income, parental education, health, and/or developmental concerns, with economic disadvantage being the primary indicator. The present sample represents a subset of children involved in three larger studies (n = 641) for whom complete data sets were available. Missingness resulted primarily from the lowercase letter knowledge task not being administered in the first cohort of a two-cohort study. The 461 children represented both genders about equally (50.3% male, n = 224; 49.7% female, n = 221; 16 not reported). The children ranged in age from 33 months to 66 months, with a mean age of 51 months at the time of testing and more than 90% between 48 and 59 months (SD = 4.70; 33–36 months: n = 1; 36–41 months: n = 24; 42–47 months: n = 13; 48–53 months: n = 269; 54–59 months: n = 148; 60–66 months: n = 6). We note that although older children tended to have greater lowercase letter knowledge, age did not interact with any of the effects we describe below. The majority (n = 422) spoke English as the primary language in their home environment, although Spanish was spoken in the homes of 11 children; home language data were unavailable for 22 children.

Children's race/ethnicity was reported to be White for 297 (68.3%) children, Black for 76 children (17.5%), Hispanic for 26 children (6.0%), Asian for five children (1.1%), Native American for two children (0.5%), and multiracial for 21 children (4.8%); the race/ethnicity of 34 children was unspecified or unavailable.

The sample involved in this study was ideal for testing the hypotheses of this study in two important ways. First, as noted previously, the children were drawn from preschool programs with targeted enrollment, such that most of the children resided in disadvantaged homes. Children who reside in disadvantaged homes tend to know significantly fewer letters during the preschool years than children from advantaged homes (Justice & Ezell, 2001; Justice et al., 2006; Lonigan et al., 1999). Although this matter is of some concern to the educational community, involving children from disadvantaged homes allows us to study alphabet knowledge in children who would have had some exposure to letters because of their age but avoids the ceiling effects typically found for older and/or more advantaged children (e.g., Mason, 1980; McBride-Chang, 1999; Treiman & Broderick, 1998).

Second, the children were enrolled in one of three larger studies investigating effects of specific preschool curricula, none of which featured a scripted or sequenced approach to alphabet instruction. All teachers reported using one of three curricula as their primary way to organize instruction: The Language-Focused Curriculum (Bunce, 1995), High/Scope (Hohmann & Weikart, 1995), or The Creative Curriculum for Preschool (Dodge, Colker, & Heroman, 2002). These three curricula present a general framework for instructional practices and targets (e.g., gross motor, dramatic play) but do not provide a systematic scope and sequence for alphabet development or any other developmental area. In addition, alphabet development (and literacy in general) does not receive any special attention; rather, it is embedded within a larger broad-based curriculum, particularly for High/Scope and The Creative Curriculum for Preschool.

General Procedure

Data were collected during a 6-week data collection period that began in April and ended in mid-May of the academic year. Each child completed a comprehensive battery of individually administered assessments over one or two 20-min sessions, depending on the child's attentiveness and on-task behavior. Assessors were university field staff who completed a rigorous training program that included (a) instruction from an experienced assessor, (b) online training modules and a written posttraining assessment, (c) observation of an experienced assessor administering each measure in the field, and (d) supervision of their first administration of the measure.

The assessment battery included the Alphabet Recognition subtests of the Phonological Awareness Literacy Screening for Preschool (Invernizzi, Sullivan, & Meier, 2001). On two separate tasks, children were presented with a sheet depicting all 26 letters in randomized order; one sheet depicted the 26 uppercase letters, and the other depicted the 26 lowercase letters. All letters were presented using Zaner-Bloser font (e.g., HIJ). Administration procedures were identical, in that the assessor pointed to each letter on the sheet and asked children to name the letter. The order of tasks was the same for all children (uppercase task then lowercase task), and unless children indicated signs of fatigue, the lowercase task was presented immediately following the uppercase task. Assessors kept a running record of letters named correctly and incorrectly using a score sheet for this purpose. The assessor did not name the letters during testing, even when they were identified incorrectly by the child. At the conclusion of the assessment session, children received a sticker and returned to their classroom. Coefficient alpha calculated for this sample was .96 for the uppercase letter task and .95 for the lowercase letter task. On average, children correctly identified 19.0 (SD = 8.2) uppercase letters and 16.3 (SD = 8.2) lowercase letters.

Given the importance of the two alphabet tasks to this study, we highlight two potential threats to the internal validity of the study. First, all children completed the uppercase task prior to the lowercase task. A potential concern is that performance on the latter task may have been influenced by the former, although it is important to recognize that any such effect would apply to all participants. Moreover, in task administration for both tasks, the children were asked to name letters, and they did not, in any circumstance, hear letter names from administrators whether their performance was correct or incorrect. Therefore, although not directly testable, it is unlikely that children learned letter names during the uppercase task and applied this learning to the lowercase task. Second, all children were administered the letters in the same randomized order. However, including presentation order did not influence our results, so it appears that order of presentation had no impact on our findings.

Results

The percentage of children knowing each of the 26 uppercase and lowercase alphabet letters is presented in Table 1. The largest percentage of children knew uppercase letters A (87%), O (86%), X (83%), S (83%), and B (83%), whereas the smallest percentage of children knew uppercase letters U (58%), V (59%), and Q (63%). For lowercase letters, the largest percentage of children knew o (84%), s (80%), and x (79%), whereas the smallest

Table 1. Alphabet letters known by children.

Uppercase letter	% of children	Lowercase letter	% of children
A	87	a	68
B	83	b	40
C	79	c	78
D	74	d	42
E	72	e	69
F	70	f	49
G	66	g	44
H	71	h	56
I	66	i	72
J	72	j	69
K	78	k	77
L	75	l	50
M	73	m	66
N	66	n	57
O	86	o	84
P	71	p	62
Q	63	q	27
R	73	r	69
S	83	s	80
T	77	t	67
U	58	u	53
V	59	v	58
W	73	w	71
X	83	x	79
Y	74	y	72
Z	72	z	69

percentage of children knew q (27%), b (40%), and g (44%). On average, children were able to identify 25 of the 26 uppercase letters at larger proportions than their lowercase letter counterparts. The only exception was the letter I; 66% of the children correctly named I, and 72% of the children correctly named i.

Data Analysis

The data were analyzed using a multilevel logistic regression with letter responses nested within children and a child-specific intercept. The four specific hypotheses and three interactions were tested using the model

$$\begin{aligned}\text{logit}[P(X_{in}=1)] = {} & \beta_{0n} + \beta_{up} * up_{ni} + \beta_{sim} * sim_i \\ & + \beta_{upXsim} * upXsim_{ni} + \beta_{first} * first_{ni} \\ & + \beta_{upXfirst} * upXfirst_{ni} + \beta_{freq} * freq_i \\ & + \beta_{upXfreq} * upXfreq_{ni},\end{aligned}$$

where $P(X_{in} = 1)$ is the probability of a correct response (i.e., $X = 1$) to letter i by child n, the βs represent regression coefficients, and the predictors are as follows:

up_{ni} is a dummy variable reflecting child n's response (correct/incorrect) to uppercase letter i.

sim_i is the visual similarity value of lowercase letter i to its uppercase counterpart (we used a standardized version of the veridical similarity values of Boles & Clifford, 1989, using the mean and standard deviation of the 26 uppercase-lowercase similarity values);

$upXsim_{ni}$ is the multiplicative interaction between up_{ni} and sim_i.

$first_{ni}$ is a dummy variable indicating whether letter i is the first letter of child n's first name or most commonly used name (i.e., nickname).

$upXfirst_{ni}$ is the multiplicative interaction between up_{ni} and $first_{ni}$.

$freq_i$ is the lowercase letter i's rank order frequency in printed English on the basis of the frequency values from Jones and Mewhort (2004), with the most frequent lowercase letter (e) given a rank of 1 and the least frequent lowercase letter (q) given a rank of 26.

$upXfreq_{ni}$ is the multiplicative interaction between up_{ni} and $freq_i$.

Note that the intercept term in the multilevel model, β_{0n}, is specific to child n. That is, each child can have a different intercept, reflecting an overall letter knowledge ability for child n independent of the predictors. Consistent with typical assumptions in multilevel modeling, the child-specific intercepts were assumed to be normally distributed. This model was estimated using SAS PROC NLMIXED. Results from this model are summarized in Table 2. We describe in detail the findings for each of the predictors.

The uppercase familiarity hypothesis was supported. Knowledge of the corresponding uppercase letter was a strong and significant predictor of lowercase letter knowledge ($\beta_{up} = 2.78$, $p < .01$). All else being equal, children who knew an uppercase letter were 16.09 times more likely to know the lowercase letter counterpart than children who did not know the uppercase letter.

The uppercase-lowercase similarity hypothesis was also supported ($\beta_{sim} = 0.16$, $p = .01$). For every standard

Table 2. Multilevel logistic regression results.

Predictor	Odds ratio	95% CI
Uppercase familiarity	16.09[a]	[11.90, 21.76]
Uppercase-lowercase similarity	1.18[b]	[1.04, 1.34]
Familiarity × Similarity interaction	2.38	[2.06, 2.76]
Own-name advantage	0.71[a]	[0.26, 1.89]
Familiarity × Own-Name Advantage interaction	2.82	[1.01, 7.95]
Frequency in printed English	0.95[c]	[0.93, 0.96]
Familiarity × Frequency interaction	0.99	[0.97, 1.01]

Note. Confidence intervals (CIs) containing 1 are nonsignificant.

[a]Odds ratio for dichotomous variable. [b]Odds ratio for a 1 *SD* change. [c]Odds ratio for 1 rank change.

deviation increase in similarity, a letter was 1.18 times more likely to be known. For example, the similarity of t to T is approximately 1 *SD* greater than the similarity of q to Q. All else being equal, a child is 1.18 times more likely to know t than q.

The interaction of uppercase-lowercase similarity and uppercase knowledge was significantly different from 0 and was a strong predictor of children's lowercase alphabet knowledge ($\beta_{up \times sim} = 0.87$, $p < .01$). For a 1 *SD* increase in similarity, the effect of uppercase letter knowledge was increased by a factor of 2.39, or a total effect of uppercase letter knowledge of 16.09 × 2.39 = 38.45. For example, the letter q is approximately 1 *SD* less similar to its uppercase counterpart than the letter t. All else being equal, the effect of uppercase knowledge for t is 2.39 times greater than for q; a child is 38.45 times more likely to know t if he or she knows T, but only 16.09 times more likely to know q if he or she knows Q.

The own-name advantage hypothesis was not supported. There is no evidence that children were more likely to know a lowercase letter if it was the first letter of their first name ($\beta_{first} = -0.35$, $p = .49$).

The interaction between knowledge of the corresponding uppercase and the first letter of the first name was significant ($\beta_{up \times first} = -1.04$, $p = .05$), such that the advantage of knowing the uppercase counterpart was increased by a factor of 2.82 to 45.38 when the letter was the first letter of the child's first name.

The frequency in printed English hypothesis was also supported. For each rank of lower frequency, a child was .95 times as likely to know a letter ($\beta_{freq} = -0.054$, $p < .01$). Taken across the entire alphabet, all else being equal, e (most frequent) was 3.8 times more likely to be known than q (least frequent).

The interaction between frequency and uppercase letter knowledge was not significant ($\beta_{up \times freq} = -0.011$, $p = .25$). There is no evidence that the effect of frequency depends on uppercase letter knowledge.

Discussion

Four hypotheses and three interactions were tested to examine theories that might help to account for children's knowledge of lowercase letters. Findings suggest that letter knowledge is guided by many of the same principles associated with other types of learning, such as word learning. Hypotheses related to children's individual experiences (i.e., the uppercase familiarity hypothesis) and their likely exposure to certain letters (i.e., frequency in printed English) are pertinent to children's developing lowercase letter knowledge. However, accurately identifying lowercase letters was not more likely when those letters were in one's own name, except as an interactive benefit when a child also knew the uppercase counterpart. In addition, perceptual characteristics of the letters (i.e., uppercase-lowercase similarity hypothesis) appear to be associated with children's lowercase letter knowledge. We discuss each of these findings in turn.

Uppercase Familiarity Hypothesis

Similar to other research (Mason, 1980; Smythe et al., 1971; Worden & Boettcher, 1990), the results from the logistic regression demonstrate that children are 16.09 times more likely to know a lowercase letter when they also know its uppercase letter counterpart, suggesting that uppercase letter knowledge helps support lowercase letter learning. Although prior evidence suggests that young children might be less willing to accept a homophone than a new label for a novel exemplar (e.g., Backscheider et al., 1999; Merriman et al., 1995), our results suggest that an anti-homophone bias may not be as relevant to children's knowledge of lowercase alphabet letters, as children may be in the process of being able to override their preference to have a novel label for a novel exemplar. Beveridge and Marsh (1991) found, for example, that the anti-homophone bias for lexical items seems to diminish sometime between 3 and 6 years of age; thus, it is plausible that a number of children in the present study, who fall within this age range, no longer exhibit this particular type of bias. Alternatively, in some cases, children may not have realized that some of the lowercase letters were different exemplars of their uppercase counterparts. It is also possible that alphabet letters are not subject to the anti-homophone bias by their very nature of existing in textual form rather than in a concrete and three-dimensional form.

Uppercase-Lowercase Similarity Hypothesis

Consistent with research concerning how children learn labels for objects (Baldwin, 1989; Landau et al., 1998; Smith et al., 1992), results show that letter features, which are akin to an object's shape, play a key role in the knowledge of lowercase letter names. That is, lowercase letter recognition is based not only on the phonetic information represented by a letter but also can be affected by children's experience with uppercase letters of similar shape. In addition, the interaction between uppercase knowledge and uppercase-lowercase similarity, one of the stronger effects in this study, provides further support for this idea. Several empirical studies have demonstrated that young children rely heavily on shape as the basis for lexical extension (Graham, Williams, & Huber,

1999; Landau et al., 1998; Merriman, Scott, & Marazita, 1993). Results of the present study expand upon this previous research by suggesting that children's knowledge of uppercase letters extends to their lowercase counterparts most effectively in cases of strong shape similarity.

Own-Name Advantage Hypothesis

Children's lowercase letter knowledge was not significantly related to whether a given letter served as the first letter of their name. This finding contrasts with previous research, which has shown that the first letter of children's first names tends to be well known by children in both uppercase (e.g., Justice et al., 2006; Treiman & Broderick, 1998) and lowercase (Treiman & Kessler, 2004) form. However, the interaction between uppercase letter knowledge and the own-name advantage uncovered in the present study indicates that the own-name advantage occurs only in the presence of knowledge of the corresponding uppercase letter—an effect overlooked in previous work. More specifically, our results suggest that children might first learn the initial letter of their first name in the uppercase form and then project this knowledge to the corresponding lowercase letter. During preschool, children demonstrate a preference for uppercase letters (Treiman, Cohen, et al., 2007) and are more likely to spell the first letter of their name in uppercase (Treiman & Kessler, 2004). Thus, when children do not know the first (uppercase) letter of their first name, the own-name advantage does not seem to provide an added benefit for their knowledge of lowercase letters.

Frequency in Printed English

In contrast to previous work (Smythe et al., 1971), children in the present study were more likely to know lowercase letters appearing more frequently in printed English than lowercase letters appearing less frequently, although the effect was relatively small when compared with the other hypotheses and interactions tested. It is possible that our findings represent the larger and more current corpus of data available for lowercase letters. Relations between lexical item frequency and acquisition of these items may also help to clarify current findings (e.g., Hoff & Naigles, 2002; Naigles & Hoff-Ginsberg, 1998; Rice et al., 1994; Wang & Koda, 2005). That is, with regard to learning lexical items, the frequency with which specific words are spoken is positively and significantly related to word knowledge for both children and adults. Recognition of lowercase letters, a type of symbolic unit, may function in a similar way. Note that the interaction between uppercase letter knowledge and the frequency in printed English hypothesis was not a significant predictor of children's lowercase alphabet knowledge. This suggests that the frequency effect seems to provide no added benefit to the relatively strong association between children's uppercase letter knowledge and their lowercase knowledge.

General Implications

Alphabet knowledge is an important and established foundation for reading (Adams, 1990; Chiappe et al., 2002; Foulin, 2005; Storch & Whitehurst, 2002) that serves as one of the most important predictors of children's word recognition in the primary grades (Schatschneider et al., 2004). In comparison with our understanding of influences on children's knowledge of uppercase alphabet letters, relatively little is known regarding children's knowledge of lowercase letters. Understanding the mechanisms underlying lowercase letter knowledge may provide crucial insights into the pathways by which children learn to read.

A key implication is that lowercase letter knowledge appears to be multiply determined. Of the four hypotheses and three interactions that we included for investigation, five were statistically significant, and the significant predictors reflected the contributions of physical characteristics of the letters, the frequency of letter usage in print, a child's knowledge of uppercase letters, and the name of the child. Our findings point to lowercase letter knowledge as a complex aspect of development, therefore implying that theories about the mechanisms underlying lowercase letter knowledge must avoid oversimplification.

Despite the complexity of lowercase letter knowledge, this study also indicates that one predictor is by far the most important—children's knowledge of the corresponding uppercase letter. Together with research noting that children tend to learn uppercase letters earlier than lowercase letters (Mason, 1980; Smythe et al., 1971; Worden & Boettcher, 1990), our study suggests that a primary pathway through which children learn the lowercase letters is a transfer of knowledge of uppercase letters to the corresponding lowercase letter. Our study also suggests that the own-name advantage and visual similarity may facilitate uppercase letter knowledge transfer to lowercase, reflected in the significant interactions even in the absence of a main effect of the own-name advantage.

A third implication warranting note is that the mechanisms underlying lowercase letter knowledge appear to be distinct from the mechanisms underlying uppercase letter knowledge. Our prior work (Justice et al., 2006) as well as that of others (e.g., Treiman & Broderick, 1998) have shown a substantial contribution of the own-name advantage to children's knowledge of uppercase letters—an association not observed in the present study. Moreover, the contribution of children's knowledge of an uppercase form with its lowercase counterpart also supports the distinctiveness of lowercase alphabet learning. The

need for future research to determine whether lowercase and uppercase letter knowledge are fundamentally different skills, potentially using factor analytic and longitudinal methods, is suggested. From a practical standpoint, the potential distinctiveness of these two aspects of early literacy knowledge may have important implications for differentiating instructional approaches.

Limitations and Conclusion

Several limitations of the present study warrant discussion. First, similar to other research (e.g., Justice et al., 2006), the present study utilized a cross-sectional design to study children's developing lowercase letter knowledge. It is possible that studying the same children over multiple points in time would have allowed us to calculate children's growing letter knowledge more precisely than our current methods and, as a result, to capture the relative contribution of our four hypotheses of interest and three interactions more accurately.

Second, our sample primarily included children residing in low-income environments in the United States, and it is not clear how well these results generalize to children from other backgrounds and other cultures, such as children from more advantaged backgrounds who tend to have more developed knowledge of print (Chaney, 1994; Justice & Ezell, 2001). For instance, in some educational communities, the teaching of letter sounds is emphasized over letter names (Ellefson, Treiman, & Kessler, 2009), and in other communities, lowercase letters are emphasized early in literacy instruction, and it is unclear whether the findings of the present study would generalize to such circumstances. Furthermore, these results may not generalize to languages other than (American) English and are, of course, not relevant for writing systems that do not have uppercase and lowercase letters (e.g., the writing systems used in Arabic and Hebrew).

Third, our approach to assessing children's alphabet knowledge employed a naming task. Perhaps use of other means for assessment, including asking children to point to (rather than name) letters or to write letters would have produced different findings. Finally, there are likely a number of child-level factors that contribute to children's development of lowercase alphabet knowledge that our study did not focus on, including age, home literacy practices, maternal responsiveness during book reading, and the overall quality of the home environment (e.g., Roberts, Jurgens, & Burchinal, 2005).

Fourth, information about the extent to which teachers engaged in sequenced attention to uppercase and lowercase letter knowledge instruction in their classrooms was not verified using a systematic classroom observation. Children were likely exposed to varying types and amounts of formal or incidental instruction in alphabet letters within their classrooms. Nevertheless, the extent to which instruction contributed to differences in children's alphabet knowledge is unclear, and we therefore make no inference from our results to inform instruction (e.g., which letters to teach, whether to teach uppercase before lowercase, whether to teach uppercase or lowercase letters only). Implication for instruction is an important avenue for future research on letter knowledge.

Conclusion

Developmental and educational researchers are deeply invested in understanding more about how alphabet knowledge evolves as well as how they might improve this aspect of development. From a practical standpoint, recent studies show there to be great variability among young children in the knowledge they possess about the alphabet at entrance to kindergarten (e.g., McBride-Chang, 1999), and studies also point to the importance of these differences for predicting who will and will not go on to be successful in reading achievement (Catts, Fey, Zhang, & Tomblin, 1999). As a result, many researchers are focused on identifying effective approaches to promoting alphabet knowledge in young children, including outcomes associated with commercially available curricula (Fischel et al., 2007). Given that relatively little is known about mechanisms that underlie children's development of alphabet knowledge (uppercase and lowercase letters), many such curricula lack a theoretical framework. Developmental research, such as that reported here, will be an important asset to the design of theoretically driven interventions focused on facilitating children's alphabet knowledge.

Theoretically, the present study contributes to a more general literature regarding children's developing knowledge of symbolic representation, which represents a fundamental pathway through which children acquire information about their world (DeLoache, 2004). Alphabet knowledge is a key form of symbolic knowledge that has been widely studied given its direct contribution to children's understanding of letter–sound correspondences (McBride-Chang, 1999; Treiman, Pennington, Shriberg, & Boada, 2008) and word recognition abilities (e.g., Mason, 1980), in addition to its predictive power for children's literacy abilities more generally (e.g., Chiappe et al., 2002). In the case of lowercase alphabet letters, children must have knowledge of these symbols, including an understanding of the link between the written symbols and the meanings they represent, as a prerequisite to becoming proficient readers of the English language (Bialystok, 1991; Bialystok & Martin, 2003). This study highlights the multifaceted nature of lowercase alphabet knowledge as well as its distinctiveness from the mechanisms underlying uppercase alphabet knowledge, and

it suggests that transfer from the uppercase may be a key foundation of lowercase alphabet knowledge.

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Appendix. Visual similarity values used (from Boles & Clifford, 1989) and frequency of uppercase and lowercase alphabet letters in printed English (from Jones & Mewhort, 2004).

Letter	Visual similarity value	Uppercase frequency	Lowercase frequency
A/a	237	3	3
B/b	263	8	20
C/c	413	5	12
D/d	242	12	11
E/e	259	11	1
F/f	359	17	15
G/g	221	19	17
H/h	321	13	9
I/i	313	6	6
J/j	379	20	25
K/k	434	22	22
L/l	255	15	10
M/m	334	4	14
N/n	304	7	5
O/o	434	16	4
P/p	413	10	16
Q/q	225	24	26
R/r	233	9	8
S/s	417	2	7
T/t	309	1	2
U/u	409	21	13
V/v	429	23	21
W/w	409	14	19
X/x	417	25	23
Y/y	309	18	18
Z/z	442	26	24

Note. For visual similarity, higher numbers indicate greater perceived similarity between the uppercase and lowercase letters. For letters, 1 represents the most frequent letter, and 26 represents the least frequent letter.